

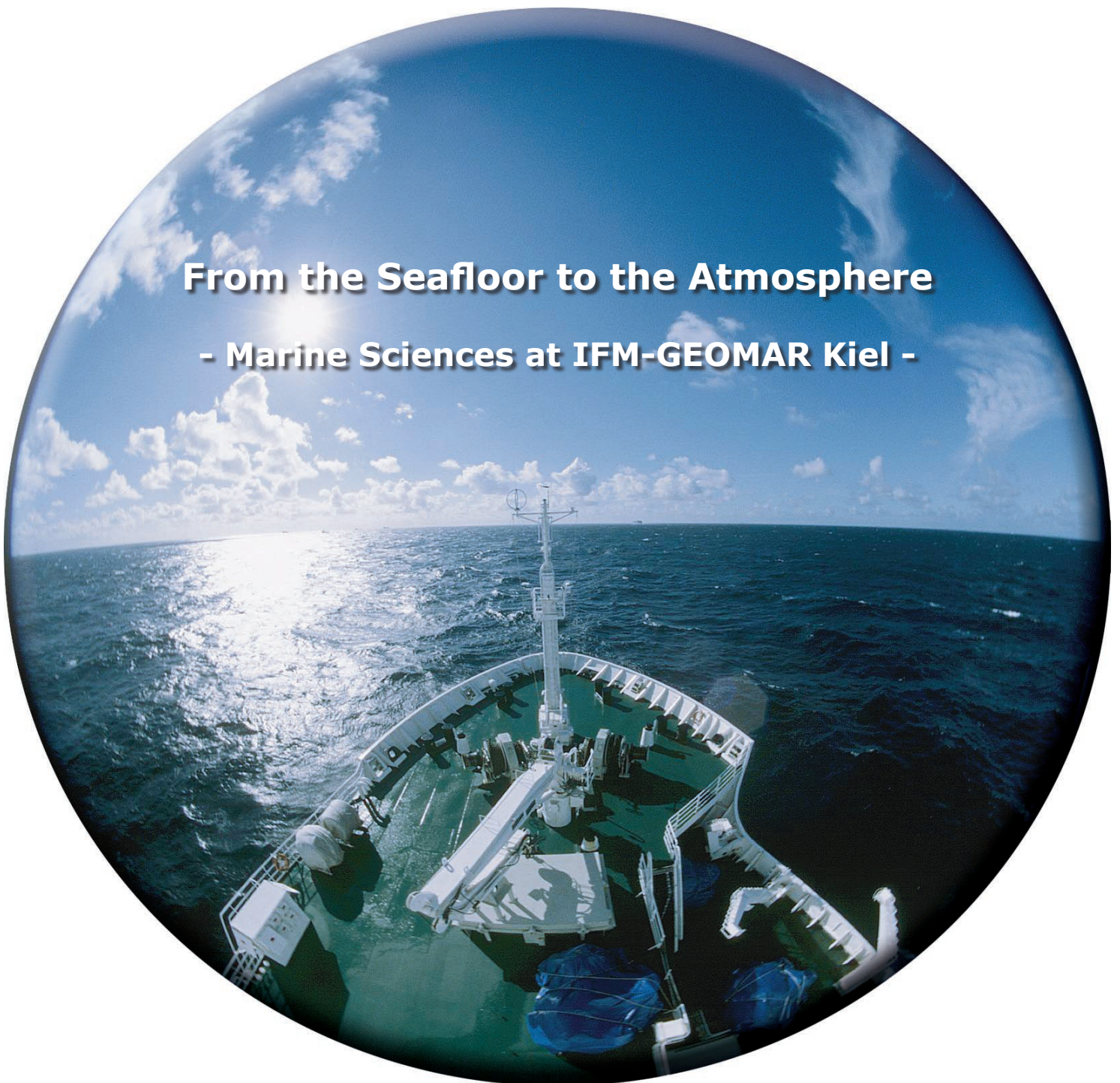


IFM-GEOMAR

Leibniz-Institut für Meereswissenschaften
an der Universität Kiel

IFM-GEOMAR Report 2005

From the Seafloor to the Atmosphere
- Marine Sciences at IFM-GEOMAR Kiel -





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IFM-GEOMAR Report 2005

Editor:
Andreas Villwock

Leibniz-Institut für Meereswissenschaften / Leibniz Institute of Marine Sciences
IFM-GEOMAR
Dienstgebäude Westufer / West Shore Campus
Düsternbrooker Weg 20
D-24105 Kiel
Germany

Leibniz-Institut für Meereswissenschaften / Leibniz Institute of Marine Sciences
IFM-GEOMAR
Dienstgebäude Ostufer / East Shore Campus
Wischhofstr. 1-3
D-24148 Kiel
Germany

Tel.: ++49 431 600-0
Fax: ++49 431 600-2805
E-mail: info@ifm-geomar.de
Web: www.ifm-geomar.de

Cover photo: Fisheye view from RV ACADEMIC SERGEJ VAVILOV on the Atlantic (John Kalisch, IFM-GEOMAR).
Inner cover: RV ALKOR (Sven Kiesche)

IFM-GEOMAR Report 2005

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Preface

2005 was an important year for IFM-GEOMAR since the institute was evaluated by the Leibniz Association. An independent group of outstanding international scientists reviewed all parts of the institute for two days. This evaluation was an important milestone in the merging process of the former institutes IfM and GEOMAR because the joint institute not only had to prove its excellence in marine sciences but also had to outline future perspectives for IFM-GEOMAR. The recommendations of the reviewers can have a substantial impact on the institute's future. Although the final recommendations have not yet been published, the preliminary results indicate that IFM-GEOMAR received a very good to excellent review. This encouraging result underpins that the merger of the two institutes was an important endeavour in order to strengthen marine sciences not only in Kiel but also nationwide. Two years after the merger, IFM-GEOMAR is recognized as a leading institution in Europe and with its broad spectrum "From the Seafloor to the Atmosphere ..." it is clearly unique in Germany.

Nevertheless, the opportunities and risks of the future ocean are even broader than the portfolio of IFM-GEOMAR. In order to address these fundamental issues, IFM-GEOMAR together with the University of Kiel, the Leibniz Institute for the World Economy and the Muthesius School of Fine Arts founded the research network "Ozean der Zukunft" (or "Future Ocean"). The network aims to provide answers to the key questions related to the oceans such as the impact of climate change or obtaining resources from the sea using a new comprehensive multidisciplinary approach joining natural sciences with economics, law, social sciences, medicine and arts. A major initiative of this network is a proposal for a Cluster of Excellence which will have an important impact on marine sciences in Kiel.

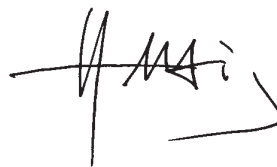


This report is written for fellow scientists, politicians and private entrepreneurs. It provides a short overview on the major developments during the past year and highlights some ongoing scientific topics, new results and major expeditions.

In order to keep this document readable, more detailed statistical information is provided in the appendices

I hope that you will enjoy reading the "IFM-GEOMAR Highlights 2005".

Kiel, October 2006



Prof. Peter M. Herzig

Overview

2005 was a very exciting and challenging year for IFM-GEOMAR. The major event for the institute in the second year after the merger was the evaluation by the Leibniz Association (WGL). A substantial amount of effort went into preparations for this event, including an evaluation of Research Division 2 (Marine Biogeochemistry) by the Scientific Advisory Board, as well as one of the Computing Centre by external experts. Fortunately, the WGL review committee attested the institute very good to excellent ratings in all departments. The final report of the evaluation will be published in 2006.

Other events that influenced the institute's development over the past year were unforeseen, such as the devastating tsunami on December 26, 2004. Due to the sound expertise in basic marine research, IFM-GEOMAR scientists were able to contribute to the investigation of the tsunami as well as to the design and installation of the Tsunami Early Warning System (TEWS) West of Indonesia. IFM-GEOMAR, along with other partners in the German Marine Research Consortium ("Konsortium Deutsche Meeresforschung" or KDM), took responsibility for the implementation of the submarine components of TEWS. For more details see page 20.

The development of TEWS also had a positive impact on the design and implementation of other multi-parameter ocean observing systems. Observational platforms such as those used in TEWS can also be equipped with other instruments in order to gather long-term data series in little-known areas of the ocean. Furthermore, other technologies for ocean monitoring are being developed and used by IFM-GEOMAR scientists. IFM-GEOMAR is the first institute in Europe to use autonomous Gliders, remotely operated instruments that glide through the ocean and have the ability to measure different physical and chemical parameters in real-time (see contribution page 14).

In addition, IFM-GEOMAR will enhance the ability for underwater observation and sampling in the near future.

Due to special funding by the State of Schleswig-Holstein, IFM-GEOMAR will purchase a Remotely Operated Vehicle (ROV) in 2006 with a diving capacity of 6000 m, as well as a new, video-controlled grab sampler with a depth limit of 6000 m.

In 2005, negotiations to relocate JAGO, the only manned research submersible in Germany, to IFM-GEOMAR were completed. JAGO will be based in Kiel beginning in January 2006, thus providing IFM-GEOMAR scientists with new research opportunities for a wide range of applications.

In order to fulfil the increasing demand for technical support of new observational devices and large-scale instruments, the institute is in the process of concentrating its technical facilities in a new Technology and Logistics Centre (TLC) at the eastshore location. Special rebuilding and renovations are presently under way and the TLC will open in spring 2006.

The computer centre of IFM-GEOMAR made considerable progress in the field of data management. Since several gigabytes of observational data and even terabytes produced by modelling, are collected every year, central management system was urgently needed. A new data manager and necessary hardware extensions marked the turning point for implementing a central data management concept at IFM-GEOMAR.

The State of Schleswig-Holstein provided considerable funding for the establishment of a Centre for Marine Substances Research in late 2005. This centre focuses on the search for new, biologically-active compounds from marine micro-organisms. It also investigates their role in biological interactions, their biosynthesis, and the identification of their chemical structures and potential application in human diseases. The role of silent genes and the function of interspecies signals and environmental factors on their expression and biosynthesis will be a major topic. The centre will function as a nucleus, stimulating and supporting new projects and initiatives in this field in

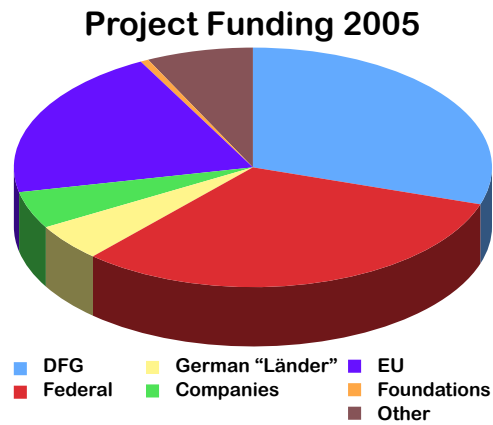


Eastshore campus of IFM-GEOMAR



Westshore campus of IFM-GEOMAR

Project funding by sources for the year 2005.



Schleswig-Holstein, and will cooperate with other scientific groups and industrial partners.

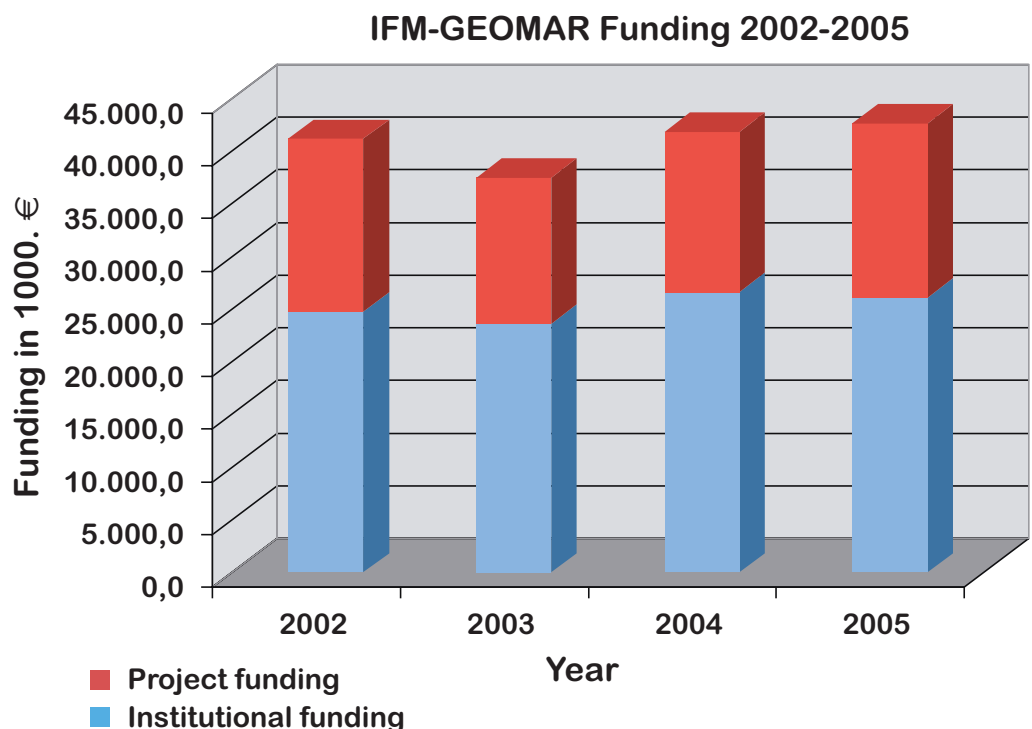
The overall project funding of IFM-GEOMAR increased in 2005 compared to the previous year by 9% and now amounts to € 16.5 Million. This comprises 39.4% of the total budget. During 2005, a number of large-scale projects were funded or initiated at IFM-GEOMAR.

- DFG-priority Programme 1162 **AQUASHIFT**, "The impact of climate variability on aquatic ecosystems", began at the end of 2004. The goal of the study is to study the impact of climate change on aquatic ecosystems, in particular shifts in the food chain and their impact on the aquatic ecosystems.
- **BECAUSE** (Critical Interactions Between Species and their Implications

for a PreCAutionary FiSheries Management in a variable Environment) - a Modelling Approach. BECAUSE investigates the quantitative role of species interactions as a first step towards the implementation of an ecosystem approach in fisheries management. The programme is funded under the 6th Framework Programme of the EU from March 2004 to March 2007.

- **CARBOOCEAN** Integrated Project aims at to assess marine sources and sinks of carbon in space and time. It focuses on the Atlantic and Southern Oceans and on a time interval of -200 to +200 years from now. The CARBOOCEAN consortium consists of 47 international groups with participating scientists from 13 European countries and the USA. The project was awarded a grant of 14.5 million Euros (2005-2009) as part of the 6th Framework Programme of the EU.
- **CASIOPEIA** (Evaluation of the Ca Isotope System in Carbonate Polymorphs as a new Proxy for Seawater Temperature and Secular Variations of Calcium Concentrations and Fractionation throughout Earth History), is an ESF funded project that brings together scientists from Germany, the Netherlands, Denmark, Austria, and Israel with an overall budget of 1.1 Mio. Euros. (November 2005 - October 2008).

Institutional funding and project funding for the years 2002-2005.



- **COMET** (Controls on METHane fluxes and their climatic relevance in marine gas hydrate-bearing sediments) addresses the complex physico-chemical and biogeochemical control parameters on marine methane fluxes and turnover rates from gas hydrate-bearing sediments into the water column and the atmosphere. COMET is a BMBF project in the GEOTECHOLOGIE programme, and is funded for a 3-year period.
- The **GITEWS** (German-Indonesian Tsunami Early Warning System) project has a total volume of 45 Mio Euros. IFM-GEOMAR is coordinating the submarine component of TEWS and receives funding of about 4.2 Mio. Euros for a 5-year funding period. The project is coordinated by the Geoforschungszentrum Potsdam (GFZ).
- **INCOFISH** (Integrating Multiple Demands on Coastal Zones with Emphasis on Aquatic Ecosystems and Fisheries) is a large EU-project with 35 institutions and private enterprises from 22 nations worldwide (12 European, 12 Latin American, 6 Asian, 5 African). It is coordinated by IFM-GEOMAR and was initiated in 2005. INCOFISH aims to conduct strategic research suitable to attaining the goals set by the World Summit for Sustainable Development in Johannesburg. This includes restoring healthy fish stocks and ecosystems by 2015. The project was awarded 4.9 Mio. Euro through the 6th Framework Programme of the EU.

IFM-GEOMAR scientists were also successful in retaining funds provided by the "Wettbewerbsfonds" of the Leibniz Association. The TRACES (Ocean – Atmosphere – Land Impacts on Tropical Atlantic Ecosystems) experiment, proposed by a consortium of four WGL institutes (Leibniz-Institut für Meereswissenschaften, Kiel, Institut für Troposphärenforschung in Leipzig, Institut für Ostseeforschung in Warnemünde, Rostock and the Potsdam Institut für Klimafolgenforschung) received about € 1 Mio. funding for 3 years. The goal of the project is to investigate important interactions in the tropical Atlantic, in particular carbon and nitrogen fluxes between land, ocean, and at-

mosphere, as well as their impact on oceanic ecosystems. Furthermore, the network aims to foster interdisciplinary education of PhD candidates.

For a complete list of projects see Appendix 3.

Scientific Developments

Amongst the IFM-GEOMAR research topics of the past year, scientific highlights were: 1) a new in-house research group that combines the disciplines of Oceanography and Geophysics, namely Seismic Oceanography (see page 12), 2) CO₂-caused ocean acidification and impact of the marine biosphere, and 3) the exploration of large cold water reefs off the coast of Norway (see page 13). Furthermore, a number of major expeditions were conducted, e.g. investigations of geological and biogeochemical processes in subduction zones off the coast of Costa Rica; hot vents at the mid-Atlantic ridge, biogeochemical studies in the subtropical eastern Atlantic and investigations of the ocean floor off the coast of Indonesia. IFM-GEOMAR used more than a third of the ship-time of the large research vessels "SONNE" and "METEOR" over the past year (see Appendix 4 for details).

IFM-GEOMAR scientists have taken the lead in planning new, large-scale research projects. Since the SFB 460 on the variability of the thermohaline circulation in the North Atlantic will end in 2006, a full proposal for a new SFB with the title "Climate - Biogeochemistry Interactions in the Tropical Oceans" is in preparation. The new SFB aims at examining links and feedback mechanisms involving climate forcing, ocean circulation and nutrient cycling that are mediated by changing dissolved oxygen levels within the ocean.

Under the leadership of the Christian Albrechts University of Kiel (CAU), IFM-GEOMAR has been very active in the development of the network initiative "Future Ocean" (see box, page 4). The network represents a cooperation between six faculties of the CAU, the "Kiel Institute for the World Economy", the Muthesius School of Fine Arts and IFM-GEOMAR. The goals of this initiative are a) to strengthen interdisciplinary marine research in Kiel involving



The Research Network "Future Ocean"

The ocean, through its dominating influence on global climate and its major role as a source of important natural resources and devastating hazards, plays a key role in the lives of all human beings. At the same time, the ocean is increasingly being altered by anthropogenic CO₂ emissions, fisheries, pollution, waste disposal and other human activities. A network of researchers at the Christian Albrecht University in Kiel (CAU) and the Kiel Institute for the World Economy, Muthesius School of Fine Arts, and IFM-GEOMAR will investigate past, present and future ocean change, explore marine resources, develop strategies for their sustainable use and study hazards arising from the seas. Marine science is by its very nature an interdisciplinary scientific field of study. The network will expand this research approach by including experts from disciplines which are not traditionally seen as marine, such as medicine, economics, social sciences and law, to study the environmental, socio-economic and legal aspects of the ocean in a truly multidisciplinary approach. Nowhere previously have experts from this wide range of disciplines and proven excellence come together to focus on questions of such key relevance to the Future Ocean. The research program will significantly broaden and enhance the understanding of the ocean. This understanding is needed to provide sound guidance to decision makers.

For more information visit: www.future-ocean.de

scientists from different faculties and disciplines such as law, medicine, economics and natural sciences and b) to develop the Cluster of Excellence, a major research initiative on topics related to the "Future Ocean".

Staff

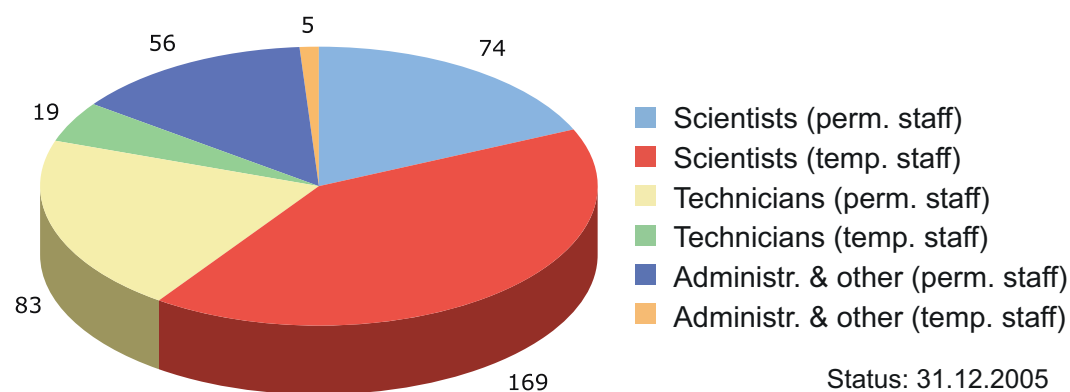
By end of 2005 IFM-GEOMAR employed 406 staff members from 17 nations, of which 243 are scientists. 71 of the scientists are women and 146 scientists are employed on project funding. For more details see Appendix 1b.

In terms of changes in academic staff, a new junior professorship in Meteorology was awarded to Prof. Dr. Kirstin Krüger. In addition, the selection and negotiation process for the W3 profes-

sorship in Marine Geodynamics was successfully completed. Prof. Dr. Jan Behrmann (Univ. Freiburg) has accepted the offer and will start in spring 2006. Still ongoing are the efforts to fill the position in biogeochemical modelling. The vacant professorships in Physical Oceanography and a replacement for the position in Theoretical Oceanography have been advertised and the selection process will also begin in spring 2006.

The successful research conducted by IFM-GEOMAR scientists is documented in a large number of peer-reviewed publications. In total, 360 journal articles (236 peer-reviewed), book contributions, and university publications were published. Five papers appeared

IFM-GEOMAR Staff



Nature & Science Papers in 2005

Beckmann, B., **Flögel, S.**, Hofmann, P., Schulz, M., and Wagner, T., 2005: Upper Cretaceous African climate development and implications for the marine carbon cycle. *Nature*, **437**, 241-244, doi: 10.1038/nature03976.

Haug, G.H., Ganopolski, A., Sigman, D.M., Rosell-Mele, A., Swann, G.E.A., **Tiedemann, R.**, Jaccard, S.L., Bollmann, J., Maslin, M.A., Leng, M.J., and Eglinton, G., 2005: The seasonal cycle in North Pacific sea surface temperature and the glaciation of North America 2.7 million years ago. *Nature*, **433**, 821-825.

Mills, M.M., Ridame, C., Davey, M., **La Roche, J.**, and Geider, R.J., 2005: Iron and phosphorus co-limit nitrogen fixation in the eastern tropical North Atlantic. *Nature*, **435** (7039), 232.

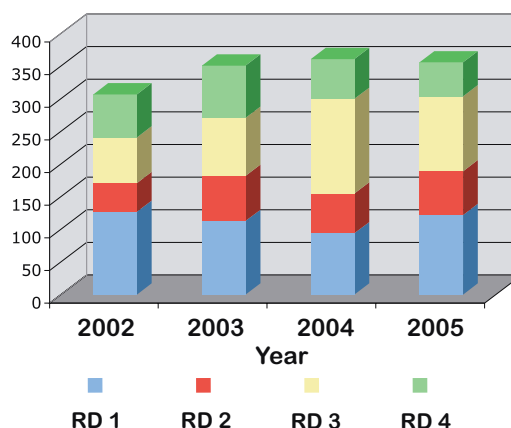
Jickells, T.D., An, Z.S., Andersen, K.K., Baker, A.R., Bergametti, G., Brooks, N., Cao J.J., Boyd, P.W., Duce, R.A., Hunter, K.A., Kawahata, H., Kubilay, N., **LaRoche, J.**, Liss, P.S., Mahowald, N., Prospero, J. M., Ridgwell, A.J., Tegen, I., and Torres, R., 2005: Global Iron Connections Between Desert Dust, Ocean Biogeochemistry and Climate. *Science*, **308**, 67-71.

Worm, B., **Sandow, M.**, Oschlies, A., Lotze, H.K., and Myers, R.A., 2005: Global Patterns of Predator Diversity in the Open Oceans. *Science*, **309**, 1365-1369.

in the high impact journals Nature and Science, two of them represented palaeoclimatic studies, another two focused on biogeochemical issues, and one was a study on marine biodiversity. For details see Appendix 5.

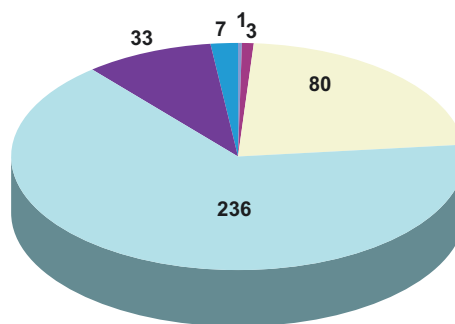
The level of scientific activities, exchange and cooperation can be documented with some key numbers: more than 300 scientific presentations (102 invited), 47 research visitors from 19 countries, 23 research visits of IFM-GEOMAR staff to other institutes, and 26 meetings organized by IFM-GEOMAR staff. For details see Appendix 7.

Publications 2002-2005



Publications 2002-2005 by research divisions

Publications 2005



Total Number: 360

- Peer-reviewed Publications
- Monographs (authorship)
- Monographs (editorship)
- Book Contributions
- Papers in other Journals
- Electronic Publications

Publications 2005 by publication type

A number of scientists were honoured for their achievements in science, science management or public outreach. Amongst them, the "Prince Albert I Medal" of the International Association for the Physical Sciences of the Ocean (IAPSO) for Prof. Friedrich Schott, emeritus in Physical Oceanography, was one of the most outstanding awards in the past year.

Student Education / Teaching

IFM-GEOMAR contributes with personnel and facilities to teaching and education at the Faculty of Mathematics and Natural Sciences of the Christian-Albrechts-University (CAU) of Kiel. During 2005, 17 PhD theses and 42 diploma theses were completed. IFM-GEOMAR is actively participating in a number of international education programs. Amongst them, the cooperation with the Ocean University of China in

Prizes and Awards 2005

Dengg, J.:

- 1. NaT-Working Preis, NaT-Working "Meeresforschung", Robert Bosch Stiftung.

Form, A.:

- Förderpreis für Nachwuchswissenschaftler des ZTS (Zentrum für Maritime Technologie und Seefischmarkt GmbH).

Kassens, H.:

- Medal of Merit, St. Petersburg State University.
- Preis für Maritime Technologie, K.E.R.N.-Region.

Herzig, P.:

- Hawley Medal of the Mineralogical Association of Canada for the best publication in Canadian Minerals (see publications).

Lube, G.:

- David Crighton Research Fellowship, University of Cambridge, 2005. (*awarded to young scholars in the field of fluid mechanics*)
- Young Scientist's Travel Award for the Poster: **Lube, G.**, Huppert, H.E., Platz, T., Sparks, R.S.J., Freundt, A., Cronin, J.S. and Procter, J.: Transport and sedimentation processes of small-volume pyroclastic flows. EGU, Vienna, Austria, 24.04.-29.04.2005.

Schott, F.:

- Starr Lecturer, Massachusetts Institute of Technology (MIT).
- Prince Albert I Medal, Internat. Association for the Physical Sciences of the Ocean (IAPSO).

Spindler, G.:

- Förderpreis für Nachwuchswissenschaftler des ZTS (Zentrum für Maritime Technologie und Seefischmarkt GmbH), 2005.

Willebrand, J.:

- "AGU Fellow", American Geophysical Union (AGU).

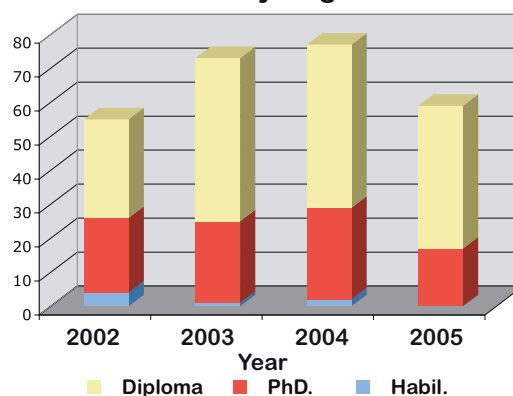
Zenk, W.:

- Deep-Sea Research-Special Edition "Direct observations of oceanic flow - A tribute to Walter Zenk". Eds.: Boebel, O., Siedler, G., Lutjeharms, J.R.E., *Deep-Sea Research II*, **52** (3-4).



Prime Minister of the State of Schleswig-Holstein, Peter Harry Carstensen with Prof. Peter Herzig at IFM-GEOMAR.

University Degrees



Qingdao jointly with Universities of Kiel and Bremen, held the first summer school in Qingdao.

Public Relations and Outreach

2005 saw a number of high level visits to IFM-GEOMAR: The (former) Federal Minister for Education and Research, Edelgard Bulmahn, the Prime Minister of the State of Schleswig-Holstein, Peter Harry Carstensen, a number of members of the federal and state parliament, the diplomatic corps, the EU-Commissioner for Fisheries and Maritime Affairs, Joe Borg, WGL President Prof. Hans-Olaf Henkel, to name only some of our most important guests.

In addition, IFM-GEOMAR established and strengthened links with a number of institutions, such as IFREMER, France and NOC, UK. These leading oceanographic institutes in Europe are now associate members of the KDM consortium. IFM-GEOMAR has also signed long-term cooperation contracts with Korea (gas hydrate research) and China (mineral resources).

In the field of public outreach IFM-GEOMAR conducted numerous activities, such as an open day with more than 2,000 visitors, an exhibition during the Kieler Woche, about 75 public lectures (see Appendix 6), a contribution to the marine fair InWaterTec, etc.

The public Aquarium of IFM-GEOMAR is visited by more than 80,000 people per year. It was closed for a major renovation in autumn 2005. Part of the basins and technical infrastructure were renewed and the Aquarium reopened in June 2006.

Introduction

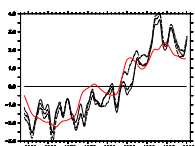
A selection of short scientific reports in this section provides an overview about research activities and results throughout 2005. This encompasses summaries from major expeditions, interdisciplinary activities, technology development and scientific results. These are just a few highlights from the broad scope of marine research at IFM-GEOMAR.

The selected contributions in this section are:

- **"Hazardous volcanoes: Evidence for water-fluxed mantle melting beneath volcanic arcs"**: A focus of Research Division 4 and the collaborative research programme SFB 574: "Volatiles and Fluids in Subduction Zones: Climate Feed-back and Trigger Mechanisms for Natural Disasters" or in short: "The subduction factory".

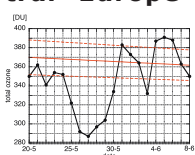


- **"Is the thermohaline circulation changing?"**: A controversial scientific discussion about whether or not the thermohaline circulation will change in future came up at the end of 2005.

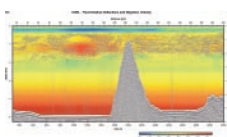


IFM-GEOMAR scientists provide their viewpoint on this topic.

- **"Episode of unusually high solar ultraviolet radiation over central Europe"**: An interdisciplinary investigation of a low ozone event in the northern Hemisphere at mid-latitudes during spring 2005.



- **"Seismic Oceanography: a new evolving field at IFM-GEOMAR"**:



methods known from geophysics are applied to investigate oceanographic problems.

More information is provided on the web pages of IFM-GEOMAR in particular under: <http://www.ifm-geomar.de/index.php?research>.

- **"The northernmost coral reefs of Europe explored by the submersible JAGO"**: A group of paleoceanographers explored cold water corals with JAGO, the only manned research submersible in Germany.



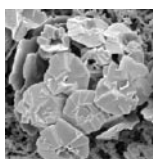
- **"Gliders - pioneering technology at IFM-GEOMAR"**: As the first institute in Europe, IFM-GEOMAR is using this new technology to observe the interior of the ocean.



- **"New insights on the impact of climate change on marine ecosystems"**: Studies in marine ecology show how climate change affects complex marine ecosystems.



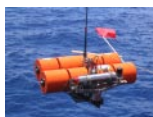
- **"The PeECE III Experiment 2005: Marine Ecosystems under pressure"**: Studying the impact of increasing CO₂ on fragile marine ecosystems in mesocosm experiments.



- **"POSEIDON Expedition 320"**: A multidisciplinary pilot study in the tropical Atlantic off the coast of Africa.



- **"Research in the Sunda Arc - The German Indonesian Tsunami Early Warning System"**: Immediately after the devastating tsunami in December 2004, IFM-GEOMAR undertook surveys for the purpose of installing an early warning system in the Indian Ocean. This is a large-scale cooperation with other groups in Germany and Indonesia.



- **"METEOR Expedition M64-2"**: Expedition to the hot vents in the Logatchev hydrothermal field on the mid-Atlantic ridge.



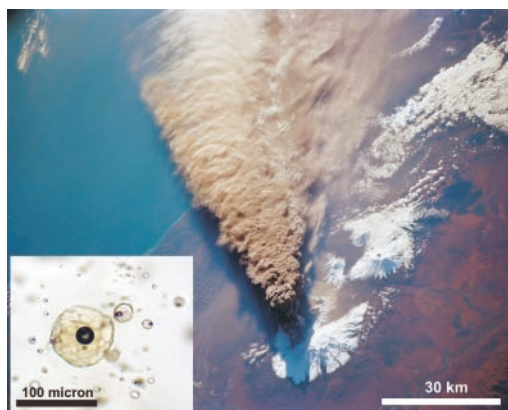
- **"METEOR Expedition M66"**: A route to the edge of the American continent". Investigations in the subduction zone off Costa Rica.



Hazardous volcanoes: Evidence for water-fluxed mantle melting beneath volcanic arcs

Volcanism along convergent margins of lithospheric plates, such as the Pacific “Ring of Fire”, is formed as a result of the subduction (sinking) of an oceanic plate beneath another plate. With increasing temperature and pressure (depth), water is released from the subducting oceanic plate into the overlying hot mantle, causing it to melt. The water-rich melt rises to the surface forming hazardous volcanoes (Figure 1).

Figure 1: Eruption of Klyuchevskoy volcano (Kamchatka) in 1994. The eruption cloud reached 20 km above sea level, and the winds carried ash as far as 1000 km SE from the volcano into the north Pacific and disrupted air routes travelled by up to 70 flights per day (10,000 passengers) (Image Science and Analysis Laboratory, NASA-Johnson Space Center). Inset demonstrates typical melt inclusions in olivine crystals from Klyuchevskoy volcano.



Although water-flux melting is commonly believed to be the dominant mechanism of mantle melting in subduction-related settings, most models for this natural phenomenon have been developed without constraints from water measurements in arc magmas.

Our studies aim to understand initial concentrations of water in magmas from two regions of active volcanism within the Pacific “Ring of Fire”, the Central American Arc and Kamchatka. These world-famous arc systems represent important end members in the global systematics of convergent margins. They have contrasting parameters of subduction, such as dip and

velocity of the subducting plate, composition of the incoming oceanic plate, the extent of subduction erosion, and the timing of volcanism. Erupted products represent all major types of arc magmas. We have examined samples from 15 active volcanoes in Central America and Kamchatka, including Klyuchevskoy volcano, the most productive arc volcano on Earth (Figure 1). Water is a volatile component in magmas and can easily escape from melts during low-pressure fractionation and eruption. In order to access the composition of potentially undegassed primitive magmas, we focused this study on microscopic melt inclusions in olivine. Inclusions are small droplets of melt trapped in crystals as they grow at depth. Once trapped, melt inclusions are isolated from later processes affecting the evolving magmatic system and preserve initial water concentrations in magmas (Figure 2).

Concentrations of water in Kamchatkan and Central American arc magmas, measured in primitive undegassed melt inclusions in olivine phenocrysts, range from ~1 wt% up to ~5 wt%, which is up to 1-2 orders of magnitude higher than in typical oceanic magmas and suggest magma origin from water-rich mantle sources. One of our key observations is the negative correlation of water in island-arc magmas with concentrations of mantle-derived elements (e.g. Ti). These correlations cannot be explained if the sub-arc mantle melts in a system closed for water input, such as in oceanic settings. Instead, these correlations suggest water-fluxed melting beneath arcs, where the extent of mantle melting is driven by the amount of water added to the mantle from external sources, e.g. from subducted oceanic plate (Figure 2). Water contents in the mantle source (calculated from the Ti content of the magmas) show a systematic decrease from up to 1 wt% in some volcanic front magmas to much lower concentrations in the back-arc in both regions, consistent with continuous metamorphic dehydration that produces progressively less water as the subducting plate sinks.

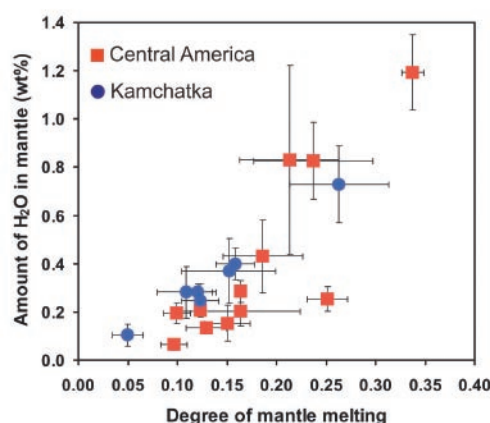


Figure 2: Correlation between estimated degrees of mantle melting and amount of water in mantle sources of Central American and Kamchatka magmas.

These results are first direct demonstration of common water-fluxed mantle melting beneath volcanic arcs. They allow a better understanding of magma generating processes at convergent margins, which cause hazardous and climate relevant volcanism and drive the recycling of elements within the Earth.

This research was supported by the Deutsche Forschungsgemeinschaft (SFB574) and the Bundesministerium für Bildung und Forschung (German-Russian cooperative project KOMEX-II).

**Maxim Portnyagin,
Seth Sadofsky and Kaj Hoernle**

The Collaborative Research Programmes

SFB 460: Dynamics of Thermohaline Circulation Variability

The Collaborative Research Programme (SFB for Sonderforschungsbereich) 460 was established in 1996 at the University of Kiel with the majority of its research located at IFM-GEOMAR. The main goal of SFB 460 is to investigate fluctuations of water mass formation and transport processes in the subpolar North Atlantic, and to gain a better understanding of their significance for the dynamics of thermohaline overturning and oceanic uptake of anthropogenic CO₂.

The SFB 460 research programme is based on a combination of observations in physical oceanography, ocean chemistry and meteorology. These observations are supplemented with a hierarchy of numerical models of medium, to very high resolution, which allow a simulation of current structures and variability across a wide range of space and time scales. Of primary interest are water mass formation processes and circulation of deep water in the subpolar North Atlantic, as well as their interaction and integral effects, in particular with respect to the uptake of anthropogenic CO₂. Furthermore, the large-scale interaction between ocean and atmosphere is investigated, both in uncoupled models and in products of joint models by collaborators, as well as paleoclimate data sets of past decades.

SFB 574: Volatiles and Fluids in Subduction Zones: Climate Feedback and Trigger Mechanisms for Natural Disasters

The Collaborative Research Programme SFB 574 investigates the role of fluid and volatile recycling in subduction zones along the Central American convergent margin (Guatemala to Panama) through integrated geophysical, geological, geochemical, petrological and oceanographic studies performed by 12 focussed projects.

The first phase (2001-2004) concentrated on a segment of the subduction zone system onshore and offshore Costa Rica and Nicaragua. An intensive field programme with a total of 7 months of seagoing expeditions and 15 man-months of fieldwork in Costa Rica and Nicaragua, as well as modelling studies over the past 2.5 years have greatly expanded and deepened the understanding of fluid migration in and out of subduction zones, the trigger mechanisms, and the probability of occurrence of natural disasters.

In Phase II (2004-2008), the focus will shift towards an accretionary segment of the Chile margin.

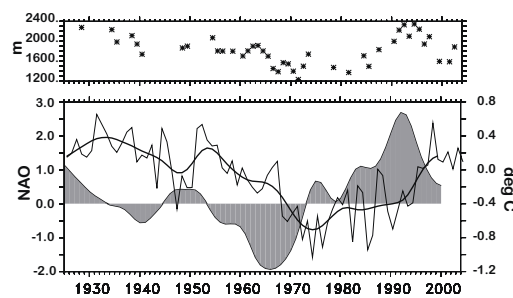
Is the Thermohaline Circulation changing?

The thermohaline circulation (THC) is a global 3-dimensional belt of ocean currents that transports large amounts of heat and freshwater. In the North Atlantic, it is manifested in a meridional overturning circulation (MOC), which, through its northward transport of warm tropical waters by the Gulf Stream and North Atlantic Current, effectively contributes to the warming of Northern Europe. It has been proposed that global warming may lead to a substantial weakening of the MOC. This trend could have a serious impact on the climate, ecology and economy of many countries surrounding the North Atlantic. However, the cooling associated with the weakening of the THC partly compensates greenhouse warming in the North Atlantic, thereby competing with the effect of global climate change in this region.

tern in the Atlantic has also been recognized as one of the main multidecadal variability modes observed during the last centuries. Thus, the dipolar SST anomaly pattern can be used as a fingerprint to detect low-frequency changes in the MOC. The SST fingerprint has several advantages. First, it is a basin-scale index, reflecting the basin-scale ocean circulation. Secondly, it effectively filters the interannual fluctuations driven by the North Atlantic Oscillation (NAO). Finally, it is easy to measure and to compute.

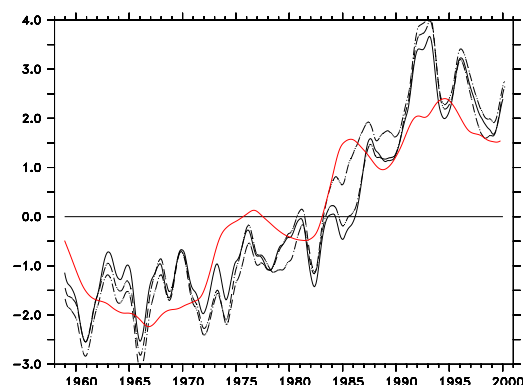
We computed an MOC index as the observed SST difference between the North and South Atlantic. The analysis reveals considerable multidecadal changes of the MOC during the last century (Fig. 1). Indications of a sustained THC weakening, however, are not evident during the last few decades. Instead a strengthening has been observed since the 1980s. These changes are likely to be the result of natural multidecadal climate variability and are driven by the low-frequency variations of the North NAO through changes in Labrador Sea convection (Fig. 1). These results are supported by a number of ocean model simulations forced by realistic atmospheric conditions (Fig. 2). Again, strong multidecadal changes are evident and an increase of the MOC from 1970 onwards is seen in response to the strengthening of the NAO (Fig. 2). The associated anomalous heat fluxes are the main forcing function, as shown by a simulation in which only the heat fluxes vary from year to year (Fig. 2). Together with global warming simulations these results indicate that the expected anthropogenic weakening of the MOC will remain within the range of natural variability during the next several decades.

Figure 1: Time series of the winter (DJFM) NAO index (shaded curve), a measure of the strength of the westerlies and heat fluxes over the North Atlantic and the Atlantic dipole SST anomaly index ($^{\circ}\text{C}$, black curve), a measure of the strength of the MOC. The NAO index is smoothed with an 11-year running mean, the dipole index unsmoothed (thin line) and smoothed with a 11-year running mean filter (thick line). Multidecadal changes of the MOC as indicated by the dipole index lag behind those of the NAO by about a decade, supporting the notion that a significant fraction of the low-frequency variability of the MOC is driven by that of the NAO. The top figure shows annual data of LSW thickness (m), a measure of convection in the Labrador Sea, at ocean weather ship Bravo, defined between isopycnals $\sigma_{1.5} = 34.72\text{--}34.62$.



Direct measurements of the MOC are rare, so that it has been difficult to quantitatively derive its low-frequency variability. One possible way to infer the relative strength of the MOC is to use sea surface temperature (SST) observations, which are available for the last century. As shown by a host of global climate model studies, variations of the MOC on multidecadal and longer timescales are accompanied by a characteristic interhemispheric SST anomaly pattern, with anomalies of opposite signs in the North and South Atlantic. This dipolar SST anomaly pat-

Figure 2: Ocean model simulations with realistic atmospheric forcing. The variability of the strength of the MOC is shown at 45°N . The black curves are different realisations with different initial conditions. The red curve is a simulation with heat flux forcing variability only. Please note the upward trend of the MOC from 1970 to the mid 1990ies.



Mojib Latif¹, Claus Böning¹, Jürgen Willebrand¹, Arne Biastoch¹, Joachim Dengg¹, Noel Keenlyside¹, Gurvan Madec² and Ulf Schweckendiek¹

¹Leibniz-Institut für Meereswissenschaften, Kiel

²LOCEAN, Paris, France

Episode of unusually high solar ultraviolet radiation over central Europe

In late May 2005 unusually high levels of solar ultraviolet radiation were observed over central Europe. In Westerland, a seaside resort on the German North Sea island of Sylt, the measured irradiance of UV-radiation exceeded the climatological mean by more than about 20% (Fig. 1a). An extreme low total ozone event for the season (Fig. 1b) coincided with high solar elevation angles and high pressure-induced clear sky conditions leading to the highest value of erythemal UV-radiation ever observed over Northern Germany in May since 1994.

The meteorological situation observed can be considered of particular medical relevance. The increase in solar UV-radiation coincided with specific weather conditions: the low ozone episode is accompanied by high-pressure, warm and sunny conditions. This tempts people to spend their leisure time outdoors. In spring, many peo-

ple tend to take their first sunbath of the season on the beaches of the seaside resorts. Accordingly, their skin is not adapted to the sun. Moreover, high levels of ultraviolet radiation are not expected by the general public during this time of year. According to official exposure categories an increase of UVI from 6 to 8 means a change from exposure category "high" to "very high" (Fig. 1a). The latter is quite unusual for Northern Germany for this time of the year.

This extreme low ozone event was caused dynamically by an elevation of the tropopause height accompanied by a poleward transport of natural ozone-poor air from the tropics in the lower stratosphere.

The resultant increase in UV-radiation is of particular significance for human health. Dynamically-induced low ozone episodes that happen in late spring can considerably enhance the solar UV-radiation in mid latitudes and therefore contribute to the UV-burden of people living in these regions.

**Carsten Stick,¹ Kirstin Krüger,^{2,3}
Nils H. Schade,¹ Henner Sandmann,¹
Andreas Macke³**

¹Institut für Medizinische Klimatologie an der Universität Kiel, Kiel.

²Alfred Wegener Institut für Polar- und Meeresforschung, Potsdam.

³Leibniz-Institut für Meereswissenschaften, Kiel

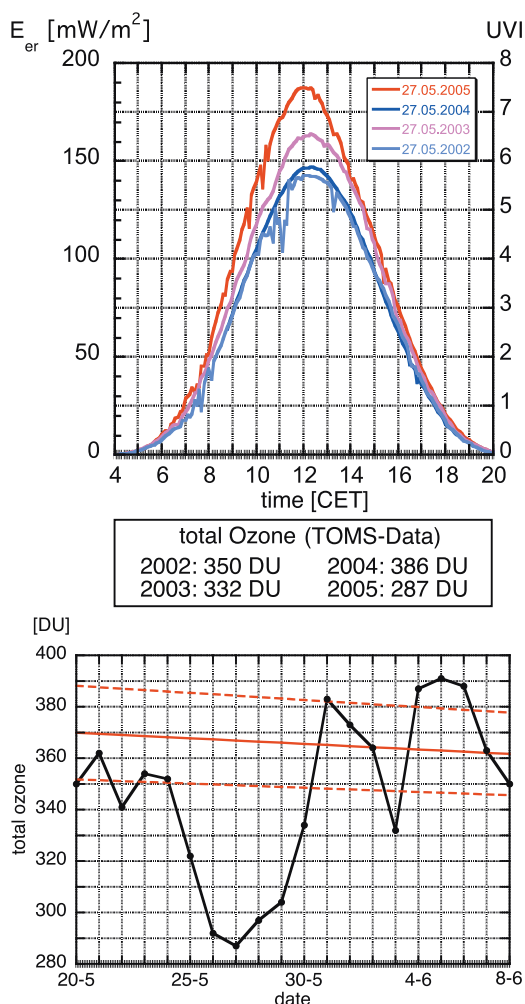


Fig. 1 (left column):
a (upper panel) Measured irradiance of erythemally effective radiation (mW/m^2) in Westerland (54.93° N, 8.31°E) on May 27, 2002 – 2005. The right y-axis gives the global UV-index;
b (lower panel) Time-series of total ozone over Westerland (black line) as measured by TOMS, May 20 – June 8, 2005. The red line shows the mean total ozone from 1979 to 2004, the dashed lines indicate the standard deviation.

Seismic Oceanography - A new evolving field at IFM-GEOMAR

In 2003 a publication in the renowned journal *Science* caused quite a stir among the usually rather separate scientific groups of physical oceanographers and seismologists. Scientists discovered that seismic data, which has been collected for several decades to study the structure of the oceanic crust, contained information possibly useful for physical oceanography. They showed that sound waves, emitted from so called "air guns", were being reflected not only from layers beneath the sea floor but also from layers within the water. It was quickly discovered that the reflections in the water column occur at places where sound waves encounter sudden changes in sound speed. This of course is of interest to physical oceanographers, who know that the sound speed in the ocean is closely related to its temperature, one of the major factors in the climate system. Further analyses revealed that the reflective layers in the water were horizontally connected over distances up to many kilometres. Due to the high horizontal resolution of seismic data, amounting to a few meters a whole new world of oceanic features have become visible and usable for physical oceanography, where typical distances between profiles are 10 to 50 km.

To make the best use of the new methods and the already existing seismic data, IFM-GEOMAR's oceanogra-

phers and seismologists met in early 2005 and formed the Interdisciplinary Project Group *Seismic Oceanography*. Since then the group has evaluated a number of seismic data sets, developed new analytical methods and tools, and planned the participation in an EU-funded experiment dedicated to seismic oceanography. The highlight of the group's work was the discovery of a 1991 seismic section cutting through an oceanographic feature known as Meddy (Mediterranean Water eddy, see Figure 1). Meddies are formed from warm and salty Mediterranean waters flowing through the Strait of Gibraltar into the North Atlantic and subsequently sinking to a depth of about 1000 m. The water follows the coast of the Iberian Peninsula northwestward as a deep boundary current and, off Cape St. Vincent, frequently detaches as 100 km wide rotating lenses, the aforementioned Meddies. These Meddies are of particular interest to physical oceanographers since Here, high temperature and salinity leads to special mixing processes known as double diffusion. They occur in locations where horizontal temperature and salinity variations counterbalance their effect on density. Driven by different molecular diffusivities of heat and salt double diffusion can lead to staircase-like temperature and salinity profiles and might be an important part of the overall mixing in the ocean. It is these staircase-like temperature profiles that can be seen so distinctively in the seismic data.

Closer examination of the reflecting layers (see close-up in Figure 2) revealed vertical excursions of the layers caused by internal waves, another process responsible for ocean mixing. Analyses of the strength of these excursions indicated elevated levels of internal wave activity near topographic features such as seamounts.

The existing expertise at IFM-GEOMAR, both in seismology and physical oceanography, and the continuing progress in Seismic Oceanography, hold much promise for future research.

Dirk Kläschen and Gerd Krahmann

Figure 1: Seismic reflection data (black and white highlights) and inferred sound speed (color) of a section off the Iberian Peninsula. The section cuts right through a lense of Mediterranean Water (oval shaped feature on the left).

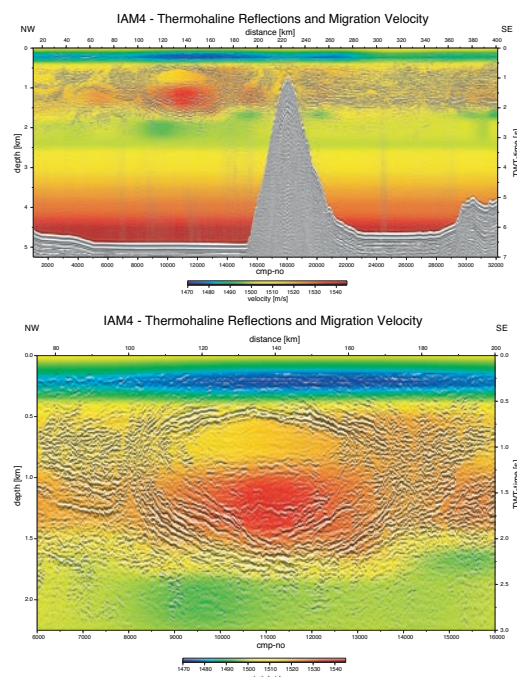


Figure 2: Close-up of the seismic reflection data shown in Figure 1. The depth variations of reflective lines are indicative of internal waves, a process important in the mixing of the oceans.

The northernmost coral reefs of Europe explored by the submersible JAGO

This cruise was part of the 6th Framework Programme of the European Commission, the HERMES (Hotspot Ecosystem Research on the Margins of European Seas) Integrated Project and aimed to understand the structure, functioning and dynamics of cold-water coral ecosystems under different trophic regimes and under different climatic settings. During the cruise we visited some of the known reef structures off Norway, among them the Trænadjupet and the Røst Reef, both south of the Lofoten Islands. The carbonate build ups in the Stjærnsund were also of particular interest. The Stjærnsund region is one of the classical sites studied by Carl Dons (1934). In all three sites, where we operated with JAGO, we discovered prolific coral growth and reef growth. However, the most spectacular site was Stjærnsund, which is characterized by giant and dense cover of living *Lophelia pertusa*.

Stjærnsund is an approximately 20 km long sound and connects the open sea (Lopphavet, SW Barents Sea) with the Altafjord. The main reef area is restricted to a distinct sill at 17°16'N and 22°28'E which forms a barrier against the strong tidal currents flowing consistently from the Lopphavet SE into the Altafjord. The sill crest depths vary between 236 m and 203 m and the adjacent troughs are 410 m (western trough) and 480 m (eastern trough) deep. The sill has an asymmetric cross-section with a gently inclined southeast flank and a steep northwest flank. The overall architecture, seabed observations and physical properties of the trough sediments point to a morainic origin of the sill with a former glacier advance through the Altafjord.

In this setting JAGO dived down on July 27th on the steep up-current slope of the sill facing to northwestward. Once we landed on the seafloor, we observed winnowed boulders up to several dm in diameter in 365 m water depth. Up-slope coral rubble was strewn between the boulders which are colonised with sponges (*Geodia*, *Axinella*), *Paragorgia arborea*, bryozoans, barnacles, and *Tubularia* hydroids. Around 337 m up-

slope, coral rubble formed up to 20 cm thick pavements which are accentuated by mega-ripples and outwash holes. The rippled character diminishes at depths shallower than 300 m. The rubble facies often show dense colonisation of *Protanthea simplex* and *Tubularia* hydroids. The sandy sediments underneath the coral rubble pavement are inhabited by *Bonellia viridis*, often in great numbers. Isolated *Lophelia* colonies, sometimes up to 1.5 m thick, with spheroidal (cauliflower) growth habit were frequently encountered from 309 m onward. Patches of *Capnella/Drifa* alcyonarians and *Geodia/Bolocera* assemblages commonly occur further upslope. All in all, there is the impression that the thick coral rubble pavement is rather a parautochthonous unit. From 290 to 250 m water depth, a unique *Lophelia* reef covering an area of 400 m across and 100 m wide had developed. The view through the window of JAGO when gliding over the



Fig. 1: Geographic map showing all study sites of the P325 cruise off northern Norway.

living corals is breathtaking (Fig. 2). Two soft tissue colourmorphs of *Lophelia* occur, an orange morph and a white one (with translucent soft tissue). Among growths of *Lophelia*, the sponge *Mycale* was frequently observed. The living outer zone of the corals seems to compete for space with *Paragorgia arborea* colonies, which occur in both



Fig. 2: *Lophelia* colonies seen through the front window of JAGO gliding over the reef of Stjærnsund in 280m water depth. (Foto: C. Dulló)

colour types (red and white). Larger colonies (generally >1 m) were concentrated on the sill top, almost forming „underwater forests“. They often fall over the side as a consequence of vigorous tidal currents. The more gently inclined eastern flank of the sill is homogeneous covered with coral rubble pavements with features similar to the western flank. Living corals only occur as isolated patches. This general pattern was confirmed by several JAGO Dives and box core samples. This

classical cold water coral ecosystem belongs to one of the most spectacular ones in the world. Only submersibles provide a method of documenting this unique reef ecosystem.

**Wolf-Christian Dullo¹ and
Andre Freiwald²**

¹Leibniz-Institut für Meereswissenschaften,
Kiel

²Universität Erlangen, Erlangen

Gliders - pioneering technology at IFM-GEOMAR



SLOCUM glider

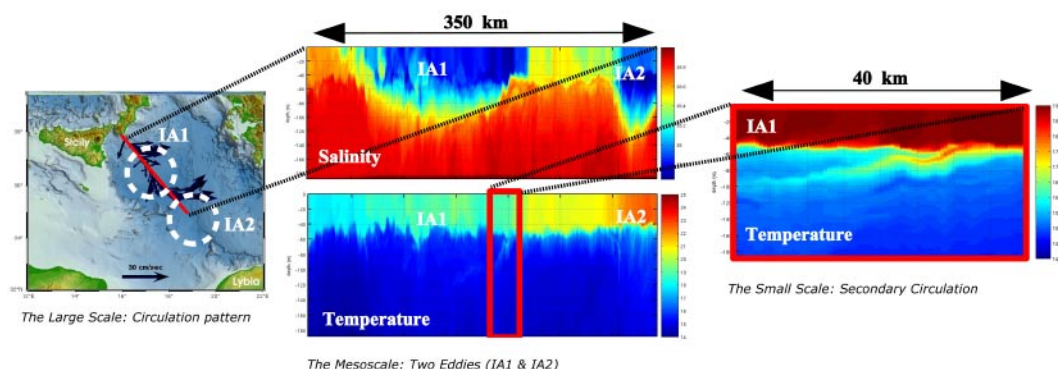
Autonomous underwater vehicles (AUV) are an emerging research platform for ocean observations. One of the most radical AUV designs is the glider that actively changes its buoyancy (by pumping small amounts of oil into a rubber bladder) to float up and down through the water column. Small wings enable the glider to transform the vertical motion into horizontal speed. Thus gliders can fly through the ocean like planes soar in the sky. A built-in compass combined with GPS navigation and cell phone communication complete this extraordinary innovative technology. IFM-GEOMAR has been conducting a number of glider experiments over the last two years and is proud to be the first European research group to apply this exciting new technology. Today, we have access to a small number of gliders to address basic research questions. We are evaluating their capability to provide key data for 'operational oceanography' - the ocean's equivalent of weather forecasting.



SPRAY glider

Gliders have a length of about 2 m and a weight of 50 kg. They can dive down to 1000 m depths four times per day. They can accomplish several month-long missions (depending on sensor load and battery type) due to their operational motto: "Go Slow". Without an energy-consuming propeller, gliders cruise through the ocean at the speed of a pedestrian and consume only 2-4 W of energy (equivalent to a flash light bulb).

Along their saw-tooth trajectories, gliders measure a variety of relevant parameters including temperature, salinity, oxygen, chlorophyll and opti-



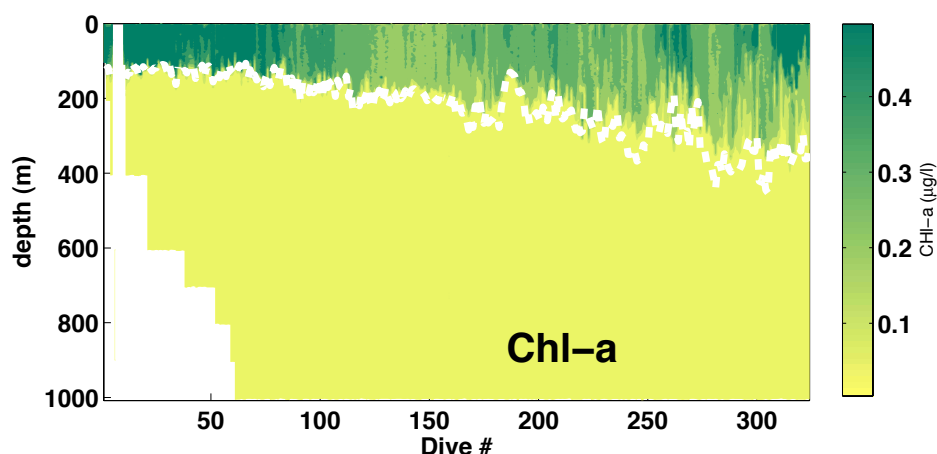
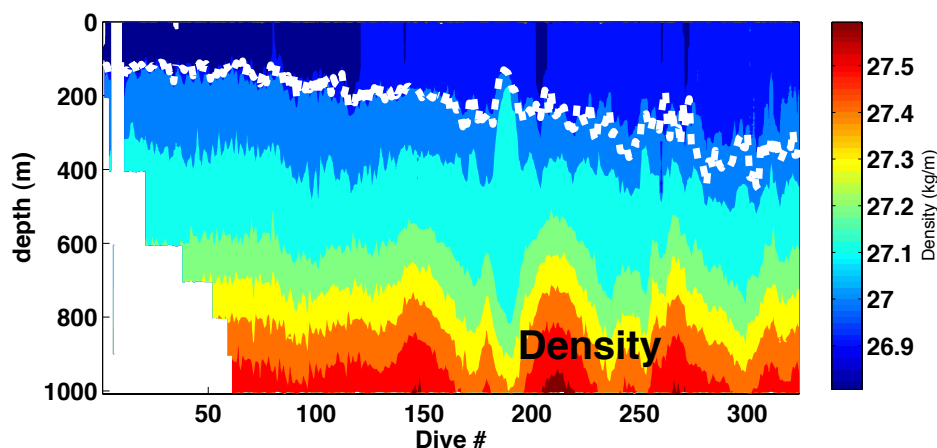
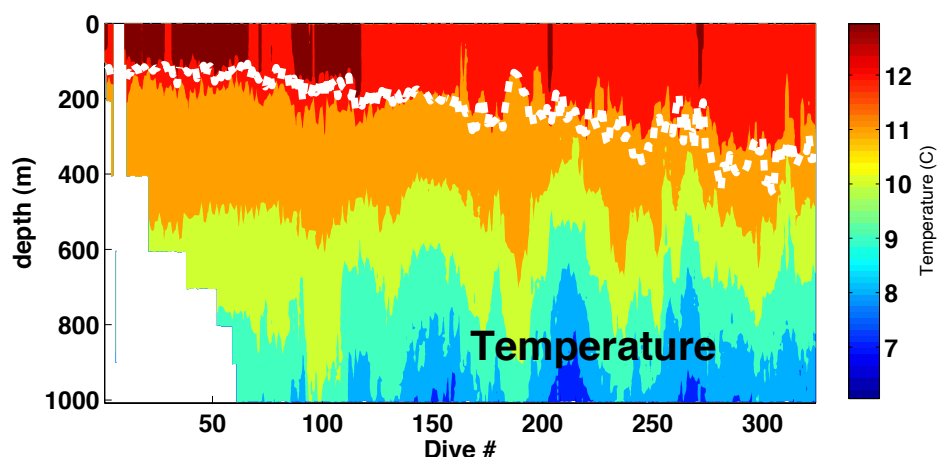
Gliders are able to resolve large-scale (left), meso-scale (middle), and small-scale (right) features of ocean circulation. An example from the Mediterranean Sea.

cal backscatter. Whenever they reach the surface, the GPS determines their position, two-way communication via satellite phone allows the exchange of information (data, missions) between the lab and the glider.

Thus far, experiments in the Mediterranean Sea and in the Atlantic Ocean have been conducted by IFM-GEOMAR using two different types of gliders: SLOCUM by WEBB Research and SPRAY by Scripps Institution of Oceanography.

Future applications will include the simultaneous use of a fleet up to 10 gliders that we call a "glider swarm". Such a concerted deployment will allow unprecedented, cost-effective, and multidisciplinary 3-dimensional surveys of the upper ocean. These experiments are especially valuable to study the physical and biogeochemical structure of eddies, frontal or upwelling processes; and to document and quantify exchange between the open ocean and its continental margins.

**Martin Visbeck and
Johannes Karstensen**



Glider as a tool for Multi-disciplinary Research: A North-east Atlantic example. The concerted measurement of Temperature and salinity and Chlorophyll-a showed that the mixed-layer deepening is not only accompanied with a Chl-a deepening but the total Chl-a content increases rather linear.



New insights into the impact of climate change on marine ecosystems

Background: Ongoing climate change will lead to profound transformations in marine ecosystems. The process of change follows several causally linked steps. CO_2 concentrations are rising in the gaseous as well as in the aqueous phases of the biosphere. In the atmosphere, CO_2 (and other climate relevant gases such as methane) lead to global warming, which in turn affect circulation patterns both in the atmosphere and in the oceans. Circulation controls the distribution and steepness of gradients in temperature and precipitation. Warming and higher precipitation may cause a regional decrease in marine salinity. In the ocean, CO_2 enrichment will lead to acidification (pH decrease by 0.3 to 1.5). These chemical and physical shifts are expected to affect biota on multiple scales.

Changes in the fitness and performance of individuals will translate into altered population dynamics. When species are affected in different ways, the strength and direction of interactions may change. Also, asynchronous shifts in species' phenology will produce mismatches of interactions. This will cause altered community structure and dynamics. Changes in local abundances and regional distribution of species will ensue. These patterns may be enhanced by changes in ocean currents transporting benthic larvae and spores. Even when only single species are affected in this manner, the effects may be system-wide if the species plays an important role, such as bivalves in coastal marine ecosystems.

In some of our current projects on the effects of climate change, we use the Baltic Sea and bivalves as model systems. The Baltic Sea is a typical example of a highly productive coastal, estuarine system. The bivalves *Mytilus edulis* and *Arctica islandica* are representatives of a globally distributed, functionally and structurally highly important group.

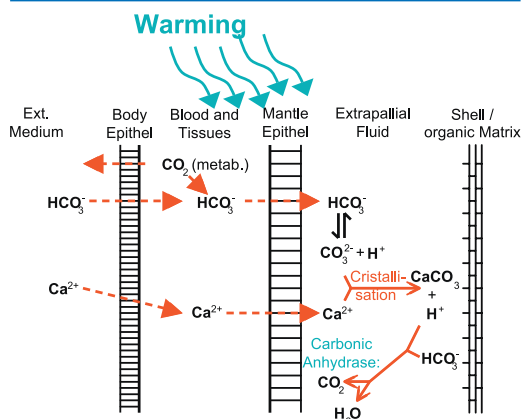
We are currently pursuing a double approach by looking into the past into the future. The first approach aims at tracing past climate changes of simi-

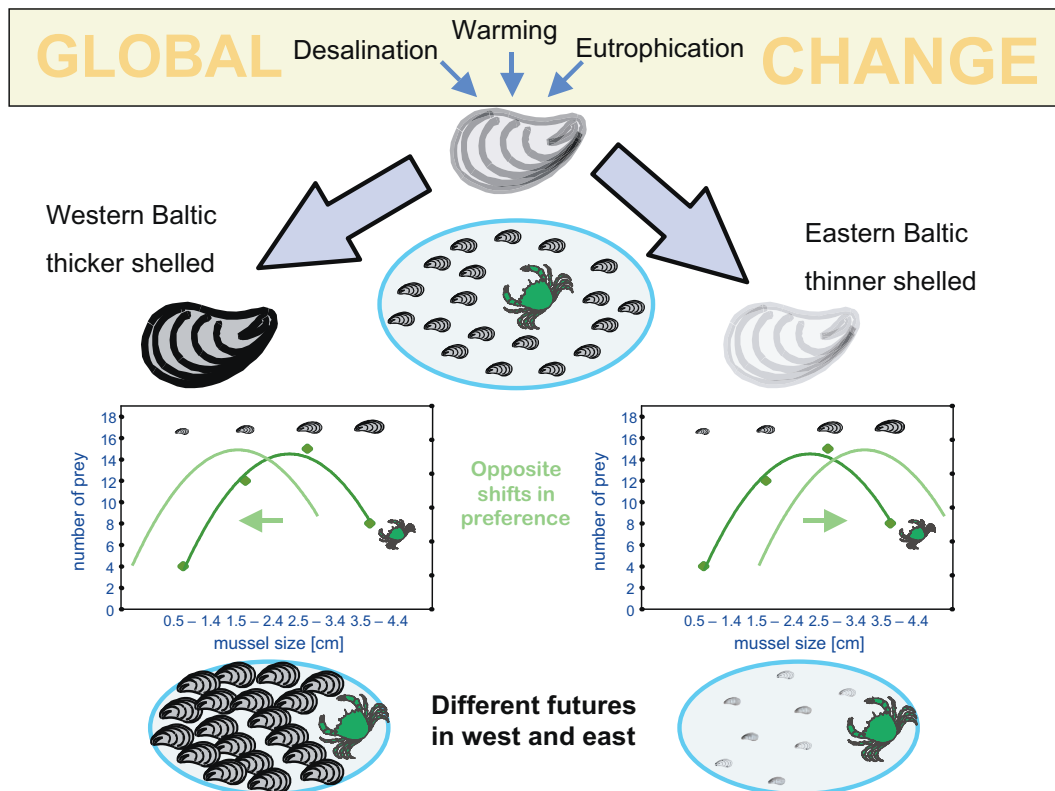
lar amplitude (albeit different rates) to help understand the processes we will face in the future.

Bivalve window into the past (ESF funded project CASIOPEIA): In order to learn from past climate changes, we have to identify and quantify them. To this end we need fossil proxies which indicate past climate parameters (temperature, salinity, CO_2 concentration, pH) with sufficient reliability and accuracy. In a collaborative project with colleagues from Research Division 2 and from four other countries we are investigating the relationship between climate parameters and stable isotope ratios and/or metal-calcium ratios in fossil-building organisms such as coccolithophorids, foraminiferans and bivalves. The necessary ground-truthing, neglected so far, is realized by growing the organisms in mesocosms with closely defined climate scenarios. Based on the results we will be able to reconstruct sections of paleoclimate using only a few fossil shells.

In order to calibrate the chemical signals of the shells, bivalves are cultivated over extended periods under controlled climate parameters: single and interactive effects of temperature, salinity and pH on $\delta^{44}\text{Ca}$ proportion and metal/Calcium ratio will be quantified. The overall aim is to establish reliable proxies for the parameters temperature, CO_2 concentration, pH, and food availability.

Mussels in a changing world (DFG funded project). In this project the goal is to assess how climate change could affect the growth rate and shell stability of *Mytilus edulis*, how these changes





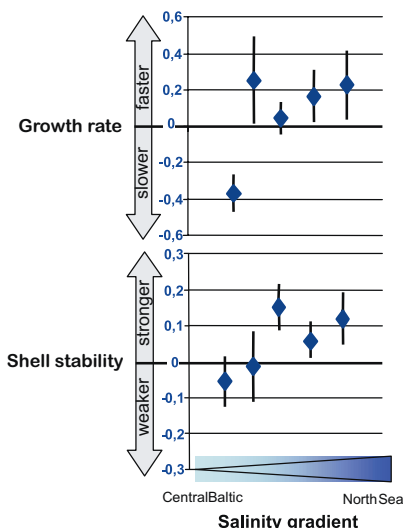
The interactive effects of desalination, warming and eutrophication on the performance of the Blue Mussel *Mytilus edulis* and the consequences for the predator-prey interaction of crabs and mussels. Mussels in the Western Baltic will be favoured under the predicted conditions. Their growth rates will increase and their shells will become thicker, thus they will be more resistant to predation by crabs and mussel abundance will increase. Mussels in the eastern Baltic, on the contrary, will experience detrimental conditions, their growth rates will decrease and simultaneously their shells will become thinner. Hence, crabs will be able to prey upon larger mussels, which will reduce reproduction and lead to a decrease in mussel abundance in the Eastern Baltic.

might affect the predation rate on the mussels, and how this might determine the fate of this key species in our region. Mussels are cultivated under scenarios predicted by recent models for the middle of this century. Different combinations of predicted temperature, salinity and food conditions are simulated. Salinity treatments are run in parallel in the field by transplanting mussels to sites for which corresponding salinity shifts are expected. Field and lab results correspond surprisingly well. From Kiel eastwards mussels will become more susceptible to predation, whereas between Kiel and Helgoland they will become more resistant to predation. Due to their enormous bio-

mass, filtration capacity, bioengineering function and function as important prey for numerous consumers, mussels play a key role in many temperate marine ecosystems. Any substantial shift in their abundance and population dynamics will entail strong changes in the benthic system - apparently with opposing signs in low versus high salinity regions.

In addition to the two-tiered investigation into the future and into the past, a novelty of our approach is that we simulate climate scenarios (multiple stressors) rather than isolated parameters. This enables us to assess not only the species reaction, but also the system response.

Changes in mussel susceptibility to predation



Links and cooperations in RD3 global change research: AQUASHIFT (RD3 & RD2), CASIOPEIA (RD3 & RD2 & 4 countries), GAME (20 countries), "Irradiation, turbulence & production" (RD3 & RD1)

**Martin Wahl, Ute Kossak,
Penpag Reuter, and Claas Hiebenthal**

Left column: Predicted climate change will lead to faster growth and thicker shells of mussels in more saline waters, and to the opposite result in less saline waters.

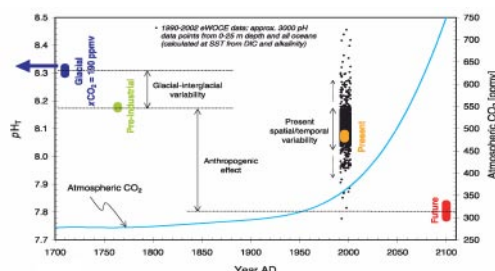


Pelagic Ecosystem CO₂ Enrichment Study

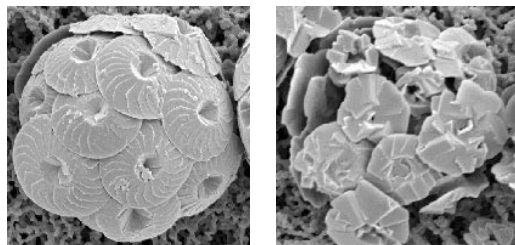
Observed and projected development of CO₂ and pH-values from preindustrial times to 2100.

PeECE III: The 2005 Mesocosm Experiment - Marine Ecosystems under pressure

If global CO₂ emissions continue to rise at current rates, the world oceans will suffer an estimated pH drop of ~0.5 units (equivalent to a 3-fold increase in the concentration of hydrogen ions) by the year 2100. This pH is probably lower than has been experienced for tens of millions of years



and, critically, is changing at a rate approximately 100 times greater than at any time over this period. Ocean acidification is essentially irreversible during our lifetime. It will take tens of thousands of years for ocean chemistry to return to pre-industrial conditions while the magnitude of ocean acidification can be predicted with a high level of confidence, its impact on marine organisms and ecosystems is largely unknown.



Coccolithophores under normal conditions (left) and under pH-values projected for the end of the 21st century.



The mesocosm facility in the Raunefjord, Norway.

tively). Over a 24-day period, the development and decline of a phytoplankton bloom was closely monitored in the 9 mesocosms.

The development of the phytoplankton community, which was dominated by diatoms and coccolithophores, was nearly identical in all CO₂ treatments. Furthermore, bacterial abundance and activity and zooplankton development and feeding rates were unaffected by CO₂ enrichment. Despite the similarity in bulk ecosystem parameters, significant differences were observed in the production of two climate relevant trace gases, dimethylsulfide (DMS) and chloriodomethane (CH₂ClI). Treatment-related differences were also obtained with regard to inorganic carbon drawdown. Whereas no difference was observed in nutrient uptake, the plankton community consumed up to 35% more inorganic carbon at elevated compared to present CO₂ concentrations. As in previous acidification experiments, calcification by coccolithophores was significantly reduced at elevated CO₂. Seawater acidification also strongly affected the development of mollusc larvae, which were reduced in number by 50% at 700 ppm CO₂ and almost disappeared in the highest CO₂ treatment.

Summary

The PeECE studies demonstrate the suitability of the mesocosm approach in examining the effects of ocean change on natural pelagic ecosystems. By covering a wide range of ecosystem parameters, the project was able to distinguish between ecosystem components and processes that are either non-responsive or sensitive to CO₂ induced seawater acidification. The results of the PeECE experiments have shown a variety of plankton community responses to ocean acidification with far-reaching implications for marine ecosystem regulation, biogeochemical cycling and air-sea gas exchange.

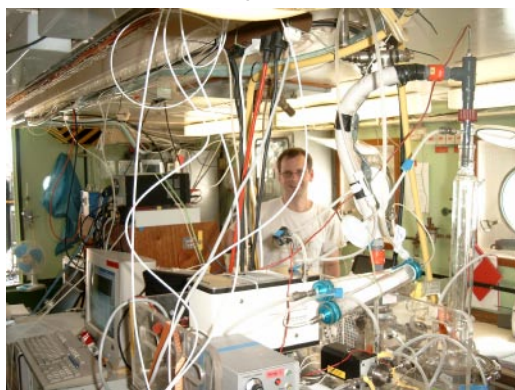
More information:

<http://peece.ifm-geomar.de>

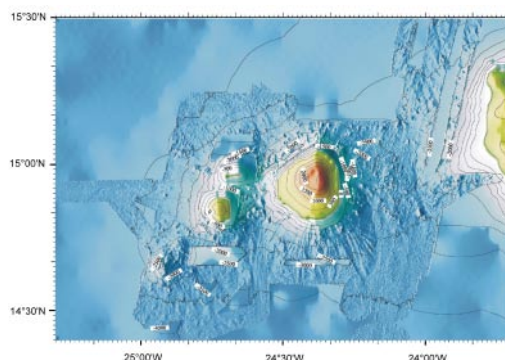
Ulf Riebesell

POSEIDON Expedition P-320: A multidisciplinary pilot study in the tropical Atlantic

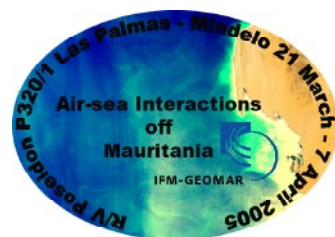
In spring 2005, the IFM-GEOMAR research vessel "POSEIDON" undertook a major expedition in the area of the tropical Atlantic off the coast of western Africa. The expedition "P320" was divided in two legs. The first one focused on marine chemistry, investigating coastal upwelling processes in a narrow band along the Mauritanian coast. The measurements provided valuable information about the physical setting of upwelling processes and the air-sea exchange of different trace gases such as carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4) and halocarbons (bromoform and others). First results show that the upwelling region off Mauritania is a strong source of atmospheric CO_2 and N_2O . CO_2 and N_2O concentrations were mirrored by O_2 concentrations, implying that both gases originated from the remineralisation of organic material before the waters were upwelled. More surprising are the results of the bromoform (CHBr_3) measurements. In contrast to our earlier hypothesis, the upwelling waters were not a strong source of atmospheric CHBr_3 .



The second leg of the cruise, POSEIDON 320/2, served as a pilot study for a multidisciplinary research project to better understand seamounts as essential systems of the world ocean. P320-2 focused on the interplay between geology, water chemistry, biogeochemistry, physical oceanography and biology at seamounts around Cape Verde. Seamounts are often characterised by enhanced productivity compared to the surrounding open ocean, thus providing important feeding grounds and critical habitats for early life stages of commercially important fish and cephalopod species. A better understanding of



the complex interplay between ecology and abiotic environments at seamounts is urgently required as exploitation strongly increased in recent years. A selection of seamounts characterized by different age and morphology in the Fogo / Brava region were the focus of further geological investigations related to natural hazard research. Within the tropical North-East Atlantic, the Cape Verde islands are the most suitable target area for this type of research. Here scientists can study numerous seamounts of different age, structure, and habitat in a relatively small area.



The working area of P-320-2 near the Cape Verde Islands.

Cephalopods sampled during POSEIDON cruise 320/2 at Cape Verde Islands in April 2005. *Onychoteuthis banksi* (early life stage, dorsal mantle length 11 mm).

Left column: Marine chemist Tobias Steinhoff keeps track of the tubing jungle in the wet lab during POSEIDON cruise 320 leg 1.

This pilot study will produce the first significant information and new results for a planned interdisciplinary project at IFM-GEOMAR and for international seamount research in general. Furthermore, it will foster development of marine research in the West African area by integrating scientists from local institutions.

The experiment also served as a pilot study of the SOPRAN (Surface Ocean Processes in the ANthropocene) project, the German contribution to the international SOLAS (Surface Ocean Lower Atmosphere) study (<http://www.uea.ac.uk/env/solas/>).

Hermann Bange and Gerd Kraus



Right column: Schematic diagram of the GITEWS System (courtesy GFZ Potsdam)

Research in the Sunda Arc – The German - Indonesian Tsunami Early Warning System

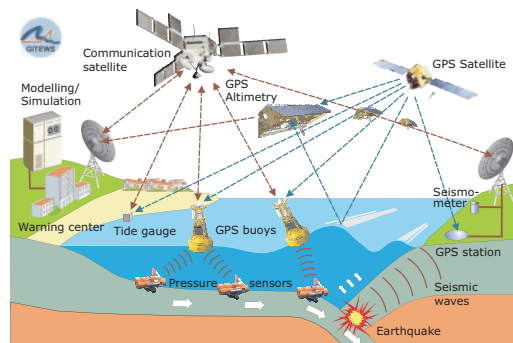
The active Sunda Arc subduction zone stretches for some 5,000 km and is the expression of the converging Indo-Australian and Eurasian tectonic plates where oceanic lithosphere is subducted beneath the Indonesian Archipelago. Its importance is revealed by the catastrophic earthquake on Boxing Day, 2004 and the related tsunami that took over 230,000 lives, mostly in Indonesia. On the other hand, because of the oblique subduction, this feature provides a unique opportunity to investigate subduction processes in detail. Early in 2005, the German government announced that it would contribute to the installation of a Tsunami Early Warning System (TEWS) in the Indian Ocean that focuses on the Indonesian coast. This project is called GITEWS (German Indonesian Tsunami Early Warning System) and comprises a multitude of sensors to be installed on- and offshore. It also involves the establishment of a Warning Centre and related efforts of warning the population of potential danger.



RV SONNE

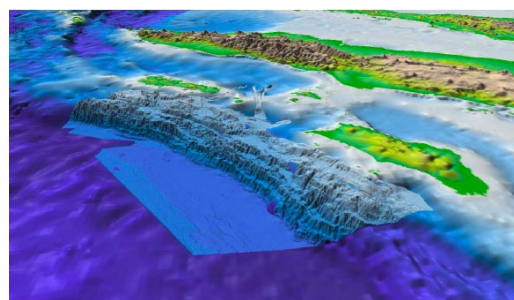
A number of research expeditions with the German research vessel SONNE were conducted between 2005 and 2006 and contributed to the overall goals of GITEWS. These cruises were partially led by IFM-GEOMAR but also by the BGR, Hannover. Since tsunami modelling will be an important part of GITEWS, bathymetric measurements of the area under investigation are an important contribution. Such measurements were the focus of the first leg of SO186 and are integral part of the project SEACAUSE that comprises the SONNE cruises SO186-1, SO186-2&3, realized immediately before and after the GITEWS cruises. Furthermore, the bathymetric measurements

were closely coordinated with British and French data collection efforts. By the end of Leg SO186-1D, about 50% of the deep water regions (>3000 m)

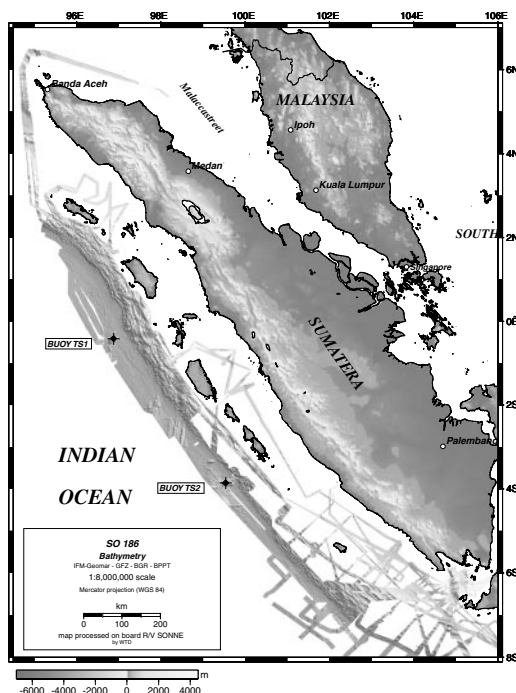


along Sumatra had been mapped. The data show considerable lateral variability along the margin. Only a few months after the cooperation agreement between Germany and Indonesia had been signed on March 14, 2005, the government of Germany handed over two experimental buoys to the government of the Republic of Indonesia. These buoys are equipped with GPS and are part of the TEWS ocean instrumentation, together with the ocean bottom units (OBUs) that contain pressure sensors. The GPS buoy and the OBU communicate via an acoustic link (modem), i.e. transferring pressure or seismological data recorded at the seafloor.

The hand-over ceremony of the buoys had already been conducted at Tanjung Priok Harbour on October 10, 2005, when Dr. Kusmayanto Kadiman - Minister of Research and Technology and coordinator of TEWS development in Indonesia - received the buoy system from Prof. Frieder Meyer Krahmer, representative of the State Secretary of BMBF (Minister of Research and Education of the Federal Republic of Germany), on board the German Research Vessel SONNE. Both, the ocean bottom



Right column: Seafloor Mapping off the Coast of Sumatra



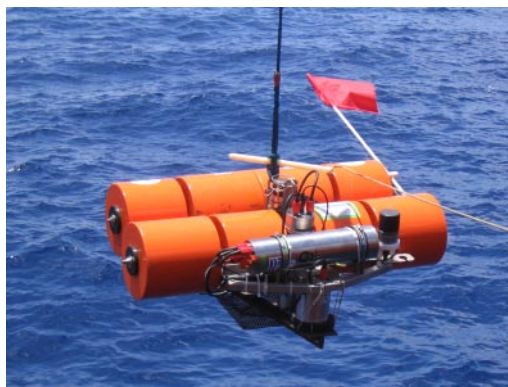
units and the surface buoys were successfully deployed during Leg SO186-1C.

SEACAUSE: "Geo-Risk Potential Along the Active Convergence Zone Between the Eastern and Indo-Australian Plates off Indonesia". This project was set about to gain insight into the natural hazard potential of the Sunda Arc subduction zone, in order to better understand the mechanism of the December 26, 2004 earthquake, to determine differences to the March 28, 2005 earthquake, to identify mechanisms that generate tsunamis, to delineate the obvious segmentation of the overriding plate, and to find indications of mass-wasting processes along the continental margin. The cruises SO186-1B, C&D substantially contributed to achieving these objectives by bathymetric mapping and subsequent interpretation of the morphology.



The Ocean Bottom Unit (OBU)

The Ocean Bottom Unit (OBU) is a modified Ocean Bottom Seismometer, outfitted with new sensors and acoustic devices and in order to fulfil the requirements of the tsunami warning ocean instrumentation system. The OBU is one of the two main marine systems; the other being the GPS buoy. The OBU is equipped with a Güralp-Seismometer and a Differential Pressure Gauge (DPG). Additionally, it measures pressure data with the Paroscientific depth sensor. It is the acoustic device, mounted on the OBU, that makes it different from the conventional OBS system. This acoustic device (modem) is responsible for the communication between the OBU and the sur-



Left column: Map of S186 cruise

Ocean Bottom Unit (OBU) deployed in Indonesian Waters

face buoy, however it also consumes a lot of energy. Therefore, an additional power supply (lithium battery), which makes the OBU bigger compared to the smaller OBS, is attached to the OBU to compensate for its extra energy consumption. Four additional floats are mounted to the OBU to counterbalance the extra weight and to ensure a safe rise during recovery.

Other German partners in GITEWS are: GeoForschungsZentrum Potsdam (GFZ) (Coordination), Alfred-Wegener-Institut für Polar- und Meeresforschung (AWI), Bundesanstalt für Geowissenschaften und Rohstoffe (BGR), Deutsches Zentrum für Luft- und Raumfahrt (DLR), Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), GKSS Forschungszentrum, Konsortium Deutsche Meeresforschung (KDM), Universität der Vereinten Nationen, Institut für Umwelt und Menschliche Sicherheit (UNU-EHS).

More information:

<http://www.gitews.de/>

Ernst Flüh

Left column: Deployment of a Tsunami buoy from RV SONNE



Black smoker Barad-Dûr in the Logatchev Hydrothermal Field (© MARUM)

METEOR Expedition M64-2: Hot vents in the Logatchev Hydrothermal Field

The R/V METEOR cruise M64/2 started on May 6, 2005 from Fortaleza (Brazil) and ended in Dakar (Senegal) on June 6, 2005 (Fig. 1). Scientists from IFM-GEOMAR, the University of Kiel, the International University of Bremen, the University of Bremen, the University of Hamburg, the University of Münster, the Max-Planck-Institute for Marine Mikrobiologie in Bremen, the Senckenberg Institute of Frankfurt, as well as scientists and technicians from MARUM in Bremen, National Oceanographic Institution in Southampton, UK, and Alstom Schilling Robotics at Davies, USA participated in this expedition. The overall goal of the cruise was to conduct geochemical, biological and microbiological studies in the Logatchev Hydrothermal Field (14°45'N at the Mid-Atlantic Ridge (MAR)). The studies placed special emphasis on the temporal variability of fluid emanations, fluid chemistry, microbial activities and associated fauna at selected vent sites in comparison to results obtained in previous METEOR cruises to this hydrothermal field. The detailed work carried out during this cruise resulted in mapping and sampling, as well as the first deployments of long term monitoring stations at the Logatchev-1 hydrothermal field (LHF-1; Fig. 2), situated on a small plateau on the eastern flank of the inner rift valley of the Mid-Atlantic Ridge at 14°45' N.

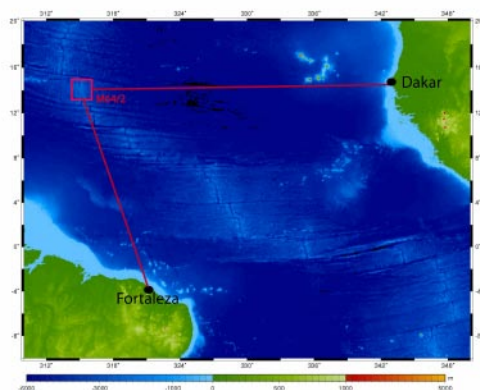


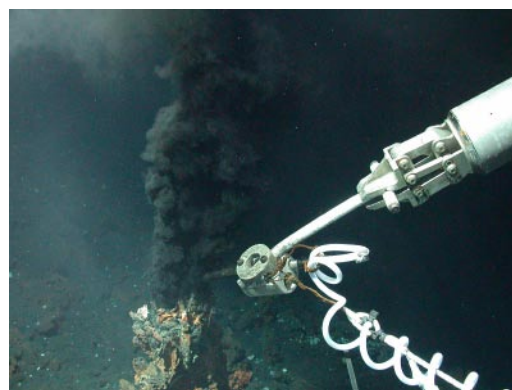
Figure 1: Map showing the track of RV METEOR during M64/2.

The main working tools during our cruise were the deep-sea Remotely Operated Vehicle (ROV) "QUEST", a TV-grab, a TV-sled and a hydrocast. At 14°45.047 N and 44°58.671 W we discovered a 5 m high active black smoker (site "A" after Gebruk et al.,

1997), which was named "Barad-Dûr" after the black tower of Mordor in the best-seller "Lord of the Rings". Based on a video and photographic survey, we were able to create a photomosaic of this tower as well as of the smoker complex at the IRINA II site. During a ROV survey northwest of the active QUEST site we found a new diffusely venting site at 14°45.31 N and 44°58.87 W.

Along CTD surveys above LHF-1, a clearly defined methane-enriched plume (up to 0.3 $\mu\text{mol/l CH}_4$) was identified between 2700 m and 2900 m water depth. Strong evidence was found for additional hydrothermal activity approximately two nautical miles northwest of LHF-1. High hydrogen concentrations ($> 50 \text{ nmol/l}$), together with a layer of increased light transmission at 3030 to 3080 m water depth, indicate the presence of venting in this area.

During 9 ROV dives we sampled a large variety of sulfides and Fe-oxid-hydroxide crusts. In addition, 7 TV grab stations with serpentinized pyroxenites, Mn-crusts, silicified crusts and atacamites completed the overall surface sampling exercise in the area of LHF-1. This was a direct continuation of the work that began in 2004 during the METEOR cruise M60/3. A total of 15 vent fluid samples were obtained with the ROV fluid sampling system. The sampled vent fluids are highly reduced and acidic, indicating a low proportion of intermixed seawater. Lowest values obtained for fluid samples were a pH of 3.9 and -370 mV for Eh. The highest



Fluid sampling with the ROV Quest (© MARUM).

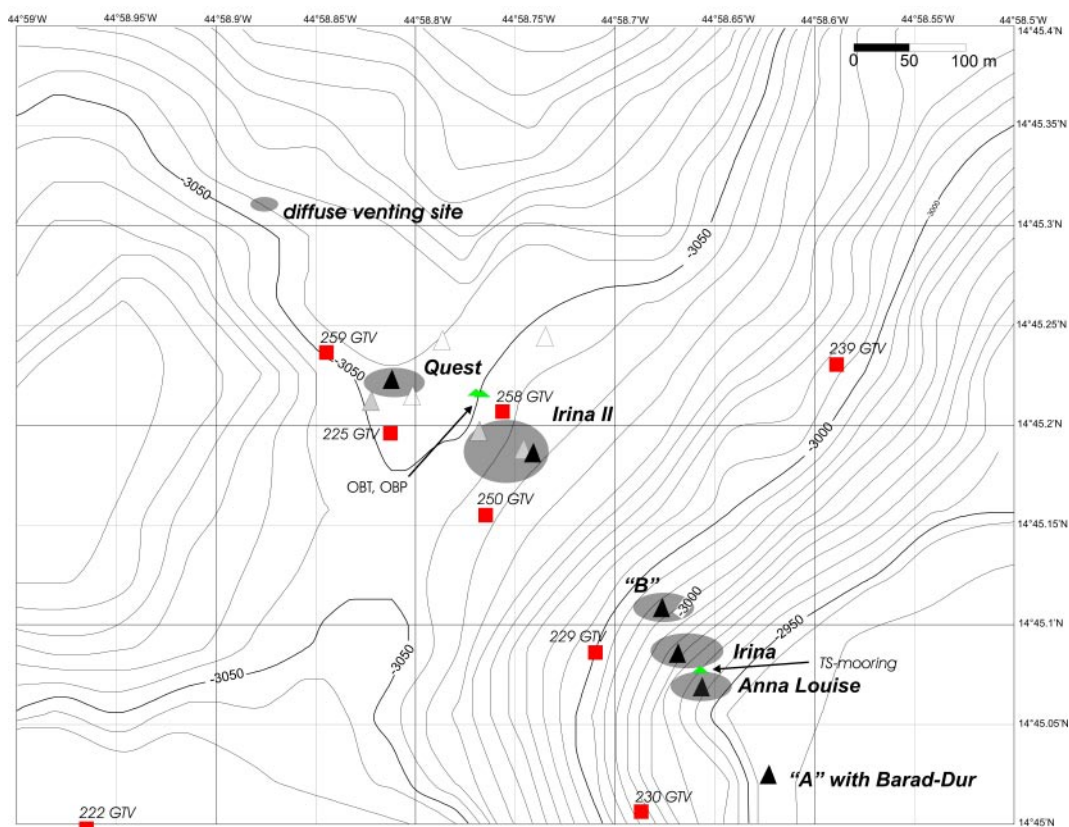


Figure 2: Map of the Logatchev-1 Hydrothermal Field showing active vent sites (black triangle), TV grab stations (red square) and instruments left on the seafloor (green triangle).

in-situ temperature measured during this cruise was 350°C at Site "B".

During this cruise, we also continued our ongoing studies of geobiological coupling at MAR vents by identifying and characterizing gradients in vent fluids in mussel beds, and collecting mussels along these gradients for analysis of the biomass and activity of the bacterial symbionts. In-situ microsensor measurements of O_2 , pH, H_2S , T and, for the first time, H_2 , were used to investigate the link between the geochemical energy supply from hydrothermal fluids and hydrothermal vent communities. These high-resolution microprofiles allowed us to determine the variability of hydrothermal fluid emission in space and time and its influence on vent communities.

An ocean bottom tiltmeter and an ocean pressure meter were deployed in LHF-1 to monitor tidal loading, micro-seismicity and recent tectonic processes over a time period of ≥ 1 year (Fig. 2). In addition, we placed a set of temperature loggers in mussel fields of the QUEST and IRINA II sites which monitor temperature variations in the biological community as a possible indicator for changes in their living environment.

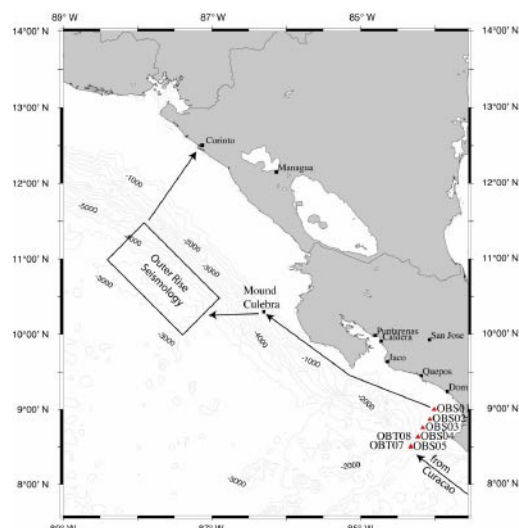
The research cruise M64/2 was carried out within the framework of the DFG-Priority Programme 1144 "From Mantle to Ocean: Energy-, Material- and Life-cycles at Spreading Axes".

**Klas S. Lackschewitz and Shipboard
Scientific Party**

METEOR Expedition M66: To the edge of the American continent

The METEOR Expedition M66 was one of the major expeditions in 2005 under leadership of IFM-GEOMAR. The expedition constitutes the main marine field expedition within the 2nd phase of the SFB 574 funded by the DFG. Five of seven legs were lead by chief scientists of the institute, comprising a total of 63 days ship-time. Leg-2a started from Curaçao with a transit section through the Caribbean to conduct oceanographic CTD stations and to prepare larger equipment for the subsequent cruise leg. After passing the Panama Canal, a geophysically oriented programme was carried out in the SFB574 working area off Costa Rica with deployments and recovery of OBS stations. 22 OBS/OBH and the deep sea observatory lander system (DOS Lander) were deployed for long-term records, addressing fluid flow and microseismicity in the subduction zone.

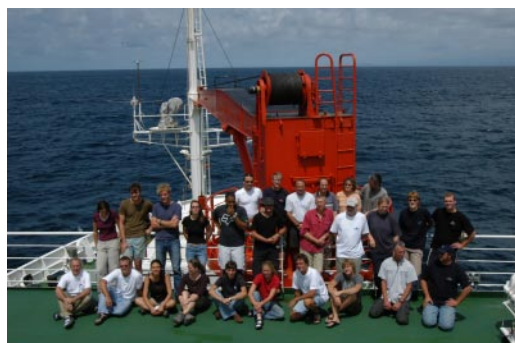
Right column: Working area off the coast of Costa Rica



were performed. Additional work included further lander deployments to study the fluid flow in the subduction area, with a main focus on the Quepos Slide, a landslide at 400 m water depth where fluids from greater depths are expelled into a nearly anoxic water column, leading to vast areas of the seafloor covered with bacterial mats. The CTD work during the cruise with a total of 37 stations also focussed on a grid above Quepos Slide, allowing an inventory of the vent-derived methane plume generated by the structure. Most of the other CTD-stations were used to resample stations already investigated several times during earlier expeditions of SFB 574 as part of a long-term survey of the methane flux from geological structures along the Middle American continental margin.

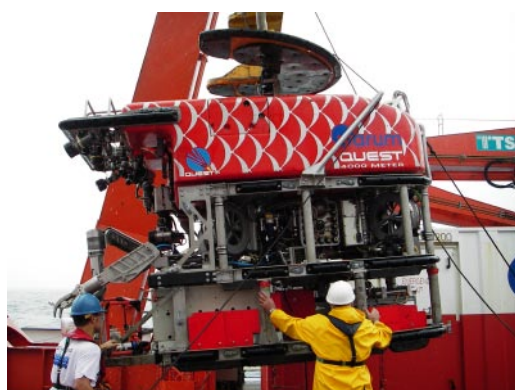
Amongst the main achievements of M66 Leg 2b are:

- The sampling of sediment core sections across the geochemical gradient at cold seep settings, which allow the 2-D modelling of fluid flow to determine the importance of non-vertical fluid circulation and convection cell formation within the sediments.
- The mapping of the active vent area at Jaco Scarp, dominated by vast fields of up to 2 m long *pogonophora* (Beard worms).
- The discovery of an active vent site in a pockmark-shaped depression, a geological structure not previously reported in the area.



The M66-2 Scientific party
(Photo: H. v. Neuhoff)

During Leg-2b (Corinto, Costa Rica – Caldera, Nicaragua), the remotely operated vehicle (ROV) Quest operated by MARUM Bremen was used to sample carbonate mounds and mud diapirs off the coast of Costa Rica and Nicaragua. A total of 15 dives at six different geological targets, including slides, mounds and a pockmark-like structure at approximately 2000 m water depth,



The ROV Quest from MARUM
on deployment from RV ME-
TEOR (Photo: H. v. Neuhoff)

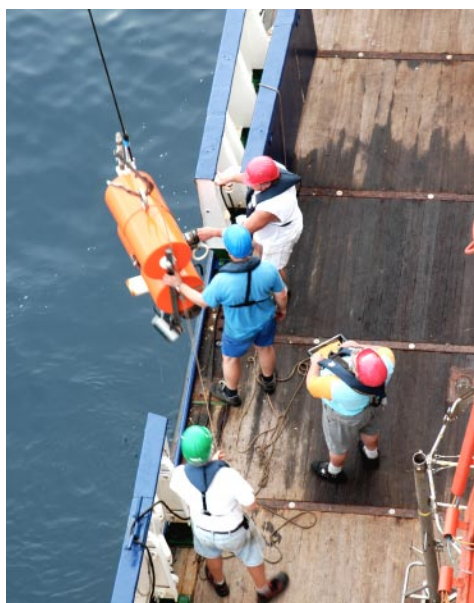


During the following Leg 3a (Caldera, Costa – Caldera, Costa Rica), the deep drilling system RockDrill operated by the BGS (British Geological Survey) was used to recover cores from the tops of five carbonate mounds. A spectacular recovery of a 3.2 m long core from the top of Jaco Scar revealed the multiphase diagenetic evolution of a biotherm on top of a subducting seamount. In addition, using a Vibro-Coringsystem, clast rich, consolidated sediments were recovered from eight different mud volcanoes. The following leg was dedicated to completing the existing inventory of core material for further tephrochronological studies in the northern part of Central America. Several heat flow surveys were carried out on the slope of the Nicaragua continental margin.

Leg 4a started on Nov. 20th from the port of Corinto, Nicaragua. The scientific work began with an investigation of the outer rise of the subducting oceanic plate. From bathymetry and previous seismic sections it was known that deep-reaching faults within the Pacific plate are reactivated when the plate starts bending towards the deep sea trench. These faults allow large amounts of water to migrate downwards as deep as the upper mantle, where the water initiates transition of rock material into serpentine. The major goal of this Leg was to use seis-

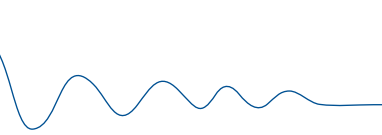
mic techniques to image changes of the physical properties of the upper mantle caused by hydration.

During Leg 2a, 22 Ocean-Bottom-Seismometers had been deployed in order to record possible micro-seismicity caused by reactivation of the faults and rock emplacement. Active wide angle seismic profiling should enable an evaluation of the velocity depth distribution within the oceanic plate, which should decrease compared to normal crust through the formation of serpentine. Preliminary onboard interpretation revealed velocities of 7.5 km/s in the upper mantle, which are an indication for the expected serpentine. Within the seismological network, 1892 earthquake events were detected within 58 days of recording, 123 of them could be located during the cruise with epicentres between 0 km and 30 km depth, which are laterally distributed from the outer rise towards the trench and underneath the continental slope. The analysis still lacks the knowledge of the exact three-dimensional velocity distribution to increase the precision of the epicentre locations, which will be provided from the ongoing modelling of the active seismic profiles. In addition high resolution seismic profiles were recorded along the continental slope to further investigate the surroundings of previously located mound structures. Deep towed multichannel seismic recordings and side scan sonar data revealed numerous mounds, which seemed to be at least in part related to faults within the slope. They provide the outlet of water



*Left column: Sampling of bacterial mats and tube worms with the ROV Quest ,
© MARUM.*

*Recovery of an OBS System
(Photo: H. v. Neuhoff)*



released from the subducting oceanic plate. Hence the internal structure and connection to the deeper crustal layers are very important for the evaluation of the water circulation within the subduction zone. Finally, a second seismological network was deployed in front of the Nicaraguan and Costa Rican coasts, which prolongs onshore installations into the marine environment. These stations are dedicated to record earthquakes used to identify the location of the seismogenic zone in the area of transition between two different regimes of oceanic plate formation.

Before METEOR started its transit to the final port of Guayaquil, Ecuador, local fishermen approached the vessel to assist during rescue of a capsized fishing boat. After two hours, the cranes of METEOR could erect the boat again and mobile pumps were used to get rid of the seawater, before the fishing boat could be towed to port by their colleagues.

***Gregor Rehder, Warner Brückmann,
and Jörg Bialas***